IPSC

BURNER MODIFICATION

PROGRAM REPORT

for

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Project No. 912350
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Ipscblup.rep

Ideas in progress

RJM

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INTRODUCTION

The IPSC boilers have been analyzed for design improvements to upgrade the durability of the coal fired burners. The existing burners experience significant mechanical stress. The inner and outer air registers and associated parts have severe thermal distortion which causes the registers to become inoperable. The aerodynamics have been examined and a swirler design made for the inner air path. Revised register settings are recommended along with an outer band to restrict inlet flow area into the outer register. The upgrade burner will have lower swirl generation in both registers. This will inhibit the tendency for gas recirculation that is evident in the existing design. The secondary air velocity with the upgrade burner aerodynamics will shape the recirculation zone to reduce NO_X formation. Structural modifications are recommended to the burner to reduce thermal stress. These incorporate a segmented outer register back plate along with radial and axial positioning means to hold the slip fit design components. Materials and thickness will remain the same as used in the existing design.

BURNER DESCRIPTION

The IPSC coal fired unit is a B&W design with 48 burners rated at 100% load for 6,100,000 lbm/hr steam leaving the superheater at 2515 psig and 1005°F. The existing burner design is shown in Figures 1 and 2 based on drawing 294361E-12. The B&W proposed design is shown on Figures 3 and 4 based on drawing SK41791E-O. A summary of the B&W proposed modification is listed in Figures 5 and 6. The recommended burner design modifications including the swirler are shown in Figure 7.

PROBLEM DESCRIPTION

The existing design problem areas are listed in Figure 8. A complete set of photos showing burner distress is in Appendix I.

The warping is caused by extreme thermal stress. Subsequent jamming of the register vanes and air slide occurs as well as relative movement which damages the rope packing air seal.

It can be seen in the photo that the inner sleeve appears distorted in the arc immediately downstream of the ignitor. It should be checked to see if any of the ignitors are firing when retracted in the burner instead of forward of the coal pipe end.

The coal pipe photos show that severe melting, resulting in egg shape ends of the pipe, is associated with coal pipe fires. In fact a photo shows that severe heat in the coal pipe elbow at the burner cover plate occurred during one fire.

AERODYNAMIC ANALYSIS

The existing burner operating conditions and register settings are shown in Figure 9. The inner air sleeve is set open 3 to 5 inches in the existing burners. Primary airflow passes with the pulverized coal. The burner secondary airflows through the outer and inner registers. Evaluation was made of the swirl number for the secondary airflow. Definition of the swirl number and its importance is listed on Figure 10. For optimum combustion and NO_X reduction, a value of 0.8 to 1.0 is desirable for the inner and outer flow. Lower outer flow swirl (.5 or less) may cause potential coal ignition problems. Higher values (approx. 1.5 or more) create over swirl, which results in an improperly sized recirculation zone and the potential of gas recirculation into the air sleeve and throat zones. The recirculation parameter is defined in Figure 11 and is a measure of the potential for gas recirculation into the air ducts. The baseline analysis for the existing burner and settings shows the potential for hot gas ingestion, which can aggravate the thermal loading on the register parts. The recommended solution was to reduce swirl in both paths by changing register settings and using a properly designed fixed vane swirler in the inner path.

Computer output of the aerodynamic calculations is listed in Appendix II for the baseline and swirler analysis.

Baseline Analysis

The secondary airflow through the registers was evaluated at a windbox-to-furnace pressure differential of 2.0 inches of water and air inlet temperature of 650°F. The airflow is a function of register or spin vane setting angle. The outer register airflow, shown in Figure 12, is 19.1 lbm/sec at 65 degrees vane exit flow angle. The inner register airflow, shown in Figure 13, is 15.2 lbm/sec at 60 degrees vane exit flow angle, corresponding to the outer register setting. The primary airflow in the coal pipe is 10.4 lbm/sec. Total flow per burner is 44.7 lbm/sec and for the furnace with 42 burners in service is 6,760,000 lbm/hr.

The swirl number is 1.64 for the outer register, shown in Figure 14, at 65 degrees vane exit flow angle. The swirl number is 1.36 for the inner register, shown in Figure 15, at 60 degrees vane exit flow angle. Swirl number for both flows is excessive based on our experience, which will produce a combustion internal recirculation that is too large. Also, since the recirculation parameter is calculated to have a negative value, there is the potential for hot gas ingestion in the duct exit The recirculation parameter is -0.2 inch of water, shown in Figure 16, for the outer duct at 65 degrees vane exit flow angle. The recirculation parameter is -0.4 inch of water, shown in Figure 17, for the inner duct at 60 degrees vane exit flow angle.

Swirler Analysis

The approach for the aerodynamic improvement was to design a swirler to provide approximately 1/3 of the burner airflow at a swirl number of 0.85.

A swirler design was employed which uses curved vanes with axial inlet angle and exit angle variation from 40° at the hub to 65° at the tip. Mechanical design of the swirler is discussed in a later section.

The swirler is used for the inner flow, which strongly effects the shape of the combustion recirculation zone. The spin vanes of the inner register will be set full open (i.e. 0 degrees flow angle) to provide axial flow into the swirler. The outer register will be set at a lower vane exit flow angle to provide reduced swirl number.

With reduced swirl in both secondary flows, the required windbox-to-furnace differential pressure is lower than for the existing burner design and register settings. Two cases were evaluated with the swirler to obtain the same secondary airflow rates as in the existing design.

a) Pressure differential of 1.19 inch of water.

In this case the outer register vane exit flow angle was set at 56 degrees. Outer register airflow was calculated to be 19.0 lbm/sec which produces a higher than desirable swirl number of 1.13 and a positive recirculation parameter of 0.25 inch of water. The flow in the inner register with the air slide open 10 inches was calculated to be 15.5 lbm/sec. The swirler generates the design swirl number of 0.85. The recirculation parameter is positive and equal to 0.98 inches of water at the swirler hub and 1.80 inches of water at the coal pipe O.D. This case avoids negative recirculation parameter, but has a higher swirl number than necessary for the outer register airflow.

b) Pressure differential of 1.99 inch of water.

In this case the pressure differential is increased, which will help provide better burner to burner airflow uniformity. This is accomplished by putting a band around the inlet to the outer register to block approximately 50 percent of the flow area as calculated at the register air door restriction. The inner register air slide will be set less open than in case (a). The band permits setting the outer register vane exit flow angle at 50 degrees. Outer register airflow was calculated to be 1.91 lbm/sec, with a swirl number of .91 and a positive recirculation parameter of .40 inch of water. The flow in the inner register with the air slide open 5 inches was calculated to be 15.0 lbm/sec. The swirler generates the design swirl number of 0.85. The recirculation parameter is positive and equal to 1.05 inches of water at the swirler hub and 1.82 inches of water at the coal pipe O.D. This case also avoids negative recirculation parameter, but has a desirably lower value of swirl number in the outer duct. The pressure differential of 1.99 inches of water is equal to the existing baseline operating value. This case (b) is recommended and will require addition of a band on the outer air register inlet, which will restrict the open flow area to 1300 square inches (5.9" open slot width).

BURNER STRUCTURAL ANALYSIS

Test Data

The existing design of Unit 2 burners was modified and set as listed in Figure 18. Measured temperatures at full load with burners "in" and "out" of service are shown in Figure 19.

Thermal Design Conditions

The heat transfer analysis design conditions are summarized in Figure 20. In service, a maximum air side convective heat transfer coefficient (HTC) of 12 Btu/hr $ft^2 {}^\circ F$ was used on the duct walls, based on velocity corresponding to 100% load airflow. Reduced (HTC) values were used in the lower velocity regions and on the surfaces exposed to the windbox. Radiation load was based on a 3200°F flame temperature and shape factors to the surfaces from mid flame position. The In-Service condition matched the measured temperature on the back plate. The Out-Of-Service conditions predicted temperatures higher than measured, which were intended to predict worst case structural loads.

Analytical Model

A finite element heat transfer and stress analysis was performed on the existing burner design, (294361E-12), the B&W proposed burner design, (SK 41791E-0), and on our recommended modified design using the COSMOS/M finite element computer program.

For the existing design, the inner sleeve, back plate, throat sleeve and front plate were modeled as an assembly using 392 axisymetric ring elements. Nodal displacements linking the front plate to the back plate were used to simulate the outer register assembly. Radiant heat flux and cooling airflows were simulated using element heat generation and surface convection coefficients. See Figure 21.

For the proposed design, only the slip-fit back plate was analyzed (using 84 axisymetric ring elements), since the unrestrained inner sleeve will be free to grow thermally and is therefore essentially stress-free. Similarly the slip-fit feature of the front plate/throat sleeve attachment relieves the thermal stress build-up between these parts so that further analysis of these parts is not required.

For the recommended modified design only the segmented back plate panels were analyzed using a 90° circular plate model consisting of 228 plane stress elements 1/2 inch thick. See Figure 22.

For the existing design and the B&W proposed design, the In-Service operating condition was evaluated based on the prescribed thermal design heat flux and airflow rates. Out-Of-Service operation was based on the full In-Service heat flux, but with the reduced (shut-down) airflow rates.

For the recommended segmented back plate design, the In-Service operating condition was evaluated based on the temperature field calculated for the proposed design. The Out-Of-Service operating condition was based on the calculated temperature field adjusted to match the maximum temperature measured for this condition.

For all cases, elastic analyses were performed. Material properties used to evaluate the designs are listed in Figures 23 through 26.

Existing Design: In-Service

The results of the heat transfer analysis are shown in Figure 27. It is seen that temperatures along the inner sleeve are generally low, but indicate a local hot spot of 875°F caused by heat flow from the back plate. A maximum temperature of 1060°F is predicted on the back plate just outboard of the inner sleeve, which is within the range 850-1220°F, measured for this condition. Low temperatures were also predicted in the throat sleeve and forward plate.

The resulting thermal growth is indicated in Figure 27A which shows the deformed finite element model, scaled for clarity, superimposed over the undeformed (room temperature) model. The radial growth of the inner sleeve is slightly greater at the back plate attachment (0.160 inch) than at either end due to the locally higher temperature at that location. Similarly, radial growth of the back plate outer diameter is somewhat larger than that of the front plate (0.301 vs 0.245 inch), skewing the outer register connecting bars (not shown). Finally it is seen that the forward end of the throat sleeve tends to move axially (0.168 inch) as well as radially (0.221 inch), assuming no restraint from the air slip seals (not shown).

The results of the stress analysis in Figure 28 showed generally low stresses along the inner sleeve except for a high (22,000 psi) local stress concentration due to the thermal growth of the back plate. The high compressive tangential stress shown in the back plate results from the hot material near the inner radius expanding against the restraint of the colder material near the outer register. For a thin plate, this type stress field will result in a circumferential coning or buckling distortion of the plate. Fracture of the weld is expected at this stress level and temperature (see photos in Appendix I) with subsequent separation from the inner sleeve and jamming of the outer register vanes.

The stresses shown in the front plate and throat sleeve are generally low except for a moderate local stress concentration at the attachment weld. The peak stress of 7600 psi at 740°F is well within the allowable stress limits previously given in Figure 23.

The results of this analysis are summarized in Figure 29.

Existing Design: Out-Of-Service

For the Out-Of-Service analysis the high radiant heat flux of the In-Service condition was imposed in order to simulate a "worst-case" loading condition.

The heat transfer analysis shows higher temperatures throughout the design, predicting a peak temperature of 1760°F on the back plate, which far exceeds the measured temperature range of 980°F - 1285°F typical for this condition. Figure 30.

The thermal growth pattern is similar to the In-Service case, but with proportionately greater deformation values.

Based on this "worst-case" temperature field, the stress analysis, Figure 31, shows very much higher compressive tangential stresses in the back plate which would severely aggravate the circumferential coning/buckling distortion already predicted to occur during In-Service operation. Additional, and more certain, separation from the inner sleeve would, therefore, be predicted with aggravated distortion of the plate and jamming of the outer register vanes.

Fracture of the front plate/throat sleeve attachment would also be predicted.

The results of this analysis are summarized in Figure 32.

B&W Proposed Design: In-Service

For this design, a finite element analysis was performed only for the slip-fit back plate since the inner sleeve is now free to grow thermally resulting in an essentially stress-free state. A similar argument applies to the separated front plate and throat sleeve where low temperatures and stresses are now expected.

The heat transfer results, Figure 33, shows the maximum temperature on the back plate is now at the inner radius, and is 25°F hotter than the existing design due to the gap between it and the inner sleeve.

The maximum compressive stress, Figure 34, has also increased slightly resulting in a slightly stronger tangential stress field than in the existing design, and therefore the same coning/buckling behavior persists in the proposed design. Jamming of the outer register vanes is also expected.

Because coning/buckling distortion is the predicted failure mode, upgrading the material to one of higher strength will have negligible beneficial effect. Increasing the thickness from 1/2 inch to 5/8 inch will provide some, but very minor, additional resistance to buckling.

The results of this analysis are summarized in Figure 35.

Proposed Design: Out-Of-Service

This analysis gave generally similar results to the In-Service results, but again with higher temperatures and stresses, further aggravating the predicted coning/buckling distortion of the plate. See Figures 36 and 37.

The results of this analysis are summarized in Figure 38.

Recommended (RJM) Modified Design: In-Service

RJM's recommended back plate design (see Figure 39) consists of four, 90° segmented panels, slip-fitted to each other and to the inner sleeve and outer register assembly of the burner assembly, previously shown in Figure 7. Overlapping plates are shown installed between the segments to minimize airflow through the gaps. Radial support bars, two for each panel, position the panels and prevent binding of the panels during operation.

A finite element stress analysis of the four panel design was performed based on the calculated In-Service temperature field. The resulting thermal growth of these panels is shown in Figure 40. It is seen that each panel is now free to grow, and for this loading, expands 0.290 inches circumferentially at the inner radius, thereby eliminating the circumferential coning/buckling failure mode of the full plate design.

The stress results of Figure 41, shows that the edges are stress free, and that the material along the inner radius is now in tension, and effectively balanced by an adjacent compressive field. Similar tensile/compressive stress fields occur in the outer region of the plate.

Note that the calculated (elastic) stresses cannot, in practice, exceed the material's yield strength, so that the peak tensile stress is limited to 18,300 psi at this temperature. See Figure 42. Plastic straining is therefore very minor, and limited to a small region along the inner radius. Furthermore, the fixed thermal strains distributed within the panel will relax due to creep, causing a gradual reduction of the stresses throughout the panel. Residual stresses resulting from the plastic strains will also gradually disappear. Failure by low cycle fatigue or creep rupture is therefore not expected.

Recommended (RJM) Modified Design: Out-Of-Service

For the Out-Of-Service condition, the calculated temperature field was adjusted to match the maximum temperature typically measured for this condition, (1285F), plus the additional 25F predicted for the slip-fit plate.

The calculated free tangential growth at the inner radius is now 0.350 inch.

The peak (elastic) stress, again at the inner radius, as shown in Figure 43, is now limited to the material's yield strength of 16,200 psi at this temperature, resulting in additional, but still minor plastic strains around the inner radius. As for the In-Service case, creep relaxation will gradually reduce these stresses throughout the panel and the residual stresses resulting from the plastic strains will also gradually disappear.

The results of this analysis and back plate design features are summarized in Figure 44.

Structural Analysis Summary

It is concluded that, during In-Service operations, the high radial temperature gradient on the back plate of the existing design, with its associated high compressive tangential stress field, results in circumferential coning/buckling of the plate with subsequent weld failures and separation from the inner sleeve. Jamming of the outer register vanes is therefore also expected. Out-Of-Service operation further aggravates the damage.

For the B&W proposed design, the slip-fit on the back plate does not relieve the high compressive tangential stress field in the plate, so that the same (or slightly more severe) coning/buckling distortion is predicted. The slip-fit feature, however, does relieve the stresses in the inner sleeve, an well as in the front plate and throat sleeve.

It was also concluded that little, if anything, would be gained by upgrading the materials or in increasing the thicknesses of the proposed design.

It is recommended that the proposed slip-fit back plate be modified by segmenting the plate into 4 separate 90° panels so as to relieve the high tangential stress field and the associated circumferential coning/buckling distortion. Jamming of the outer register doors will then also be eliminated. To ensure free thermal growth of all four panels when installed, a tangential gap of 0.75 inch is recommended between panels, with radial gaps of 0.25 and 0.50 inch at the inner and outer radius respectively.

It is also recommended that the B&W proposed inner sleeve and slip-fit front plate/throat sleeve designs remain as proposed except for the inclusion of radial support bars.

The structural conclusion and recommendations are summarized in Figure 45.

Finally it is recommended that the same materials and thicknesses of the existing design be used through out. See Figure 46.

Swirl Nozzle Mechanical Design

The recommended Swirl Nozzle design consists of 40 vanes welded to an outer and inner shroud as shown in Figure 47. Both the outer and inner shrouds are segmented to permit free thermal growth of the assembly, thereby relieving the unit from high locked-in thermal stresses. A finite element analysis was therefore not performed since the structure is essentially free of thermal stresses.

Installation of the swirler is shown in Figure 48. Cutouts (dimensions and locations supplied by IPSC) in the swirler vanes permit clearance for the ignitor, scanner and observation port. These are mirror images for CW and CCW swirlers. The unit is attached at the outer shroud to the coal nozzle by 16 support straps, 2 per segment, to allow for free thermal growth between the (hotter) outer shroud and the (cooler) coal nozzle. Locking pins, fitted to the inner shroud, permit free radial and tangential thermal growth of the segments while constraining axial movement of the segments along the inner shroud. The swirler is constructed of high temperature stainless steel (SS310).

A summary of the swirler mechanical design features is listed in Figure 49.

CONCLUSIONS AND RECOMMENDATIONS

- Aerodynamic analysis indicates that high swirl numbers associated with the inner and outer register airflow are excessive (approximately 1.5) and have the potential for hot gas recirculation into the air cavities.

- A swirler for the inner airflow will lower and provide a constant swirl number of 0.85.

- A band (or perforated screen) is recommended for the outer register inlet to permit it to be operated at a reduced exit vane flow angle and thus reduce its swirl number.

- Structural analysis confirms that the high radial temperature gradient on the outer register back plate of the existing design with its associated high compressive tangential stress field results in circumferential coning/buckling of the plate with subsequent weld failures and separation from the inner sleeve. Jamming of the outer register vanes is therefore also expected.

- Recommended additional burner modifications are:

  - Segmented back plate panels with slip fit clips and radial positioning support.

  - Outer register vane assembly radial and axial position struts.

  - Throat sleeve with slip fit clips to register and radial position bars.

  - The separate outer ring design for the air seal will avoid radial thermal growth problems, but the air seal stop must be modified to permit axial movement.

- The same materials and thickness of the existing design can be used with the recommended burner design modifications.

- The recommended burner design modifications and material selections are being provided by the RJM Corporation, with the understanding that the final design decision and implementation shall be the responsibility of the Intermountain Power Service Corporation and the Babcock and Wilcox Company.

NO_X PREDICTION

As a means to estimate the impact of the MZ Flame Stabilizer and recommended register settings on NO_X emissions, RJM reviewed the latest relevant literature. In that review, several items became evident to us. For dual register burners, a significant amount of swirl number optimization work has taken place in recent years. Work done by LaRue in the early 80's showing outer swirl numbers of .6 to .7 and inner swirl numbers of 1.3 to 1.4 as being recommended practice or normal operation (Figures 50 and 51). Jeremiejczyk in 1978 shows studies over a range of both swirl numbers in the inner from 0 to .75 and the outer from .4 to 1.2. Jeremiejczyk and others also found that the outer swirl number should be greater than .5 to assure ignition point and flame stability with various coal types. Current operation at IPSC has the following swirl number settings:

Inner = 1.36

Outer = 1.64

The RJM recommendations for swirl numbers are:

Inner = .84 (MZ Stabilizer)

Outer = .91

The outer swirl number is larger than RJM's experience would dictate which is heavily influenced by prior investigators and their measured ignition/flame stability limits on oil and gas units. However, the fuel volatility and swirl number interdependence indicated by Jeremiejczyk clearly indicates higher swirl numbers would be beneficial for ignition and flame stability as the relative volatility of the fuel decreases. Based on this research, RJM has adjusted IPSC's swirl numbers accordingly.

In terms of NO_X, if we use Figure 52 with the closest comparisons to current IPSC swirl settings and RJM recommendations, a lower O_2 profile is seen to exist on the centerline with lower temperatures (perhaps 20°C). Ignoring the O_2 difference (which helps the MZ stabilizer NO_X), the temperature difference would indicate perhaps as much as 14% NO_X reduction using RJM scaling factors. Obviously, an exact NO_X prediction is not possible, but at least the recommended settings and hardware will tend to drive NO_X down from current levels; perhaps as much as the calculated 14%.

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INTERMOUNTAIN POWER PROJECT EXISTING DESIGN (REF. 294361E-12)

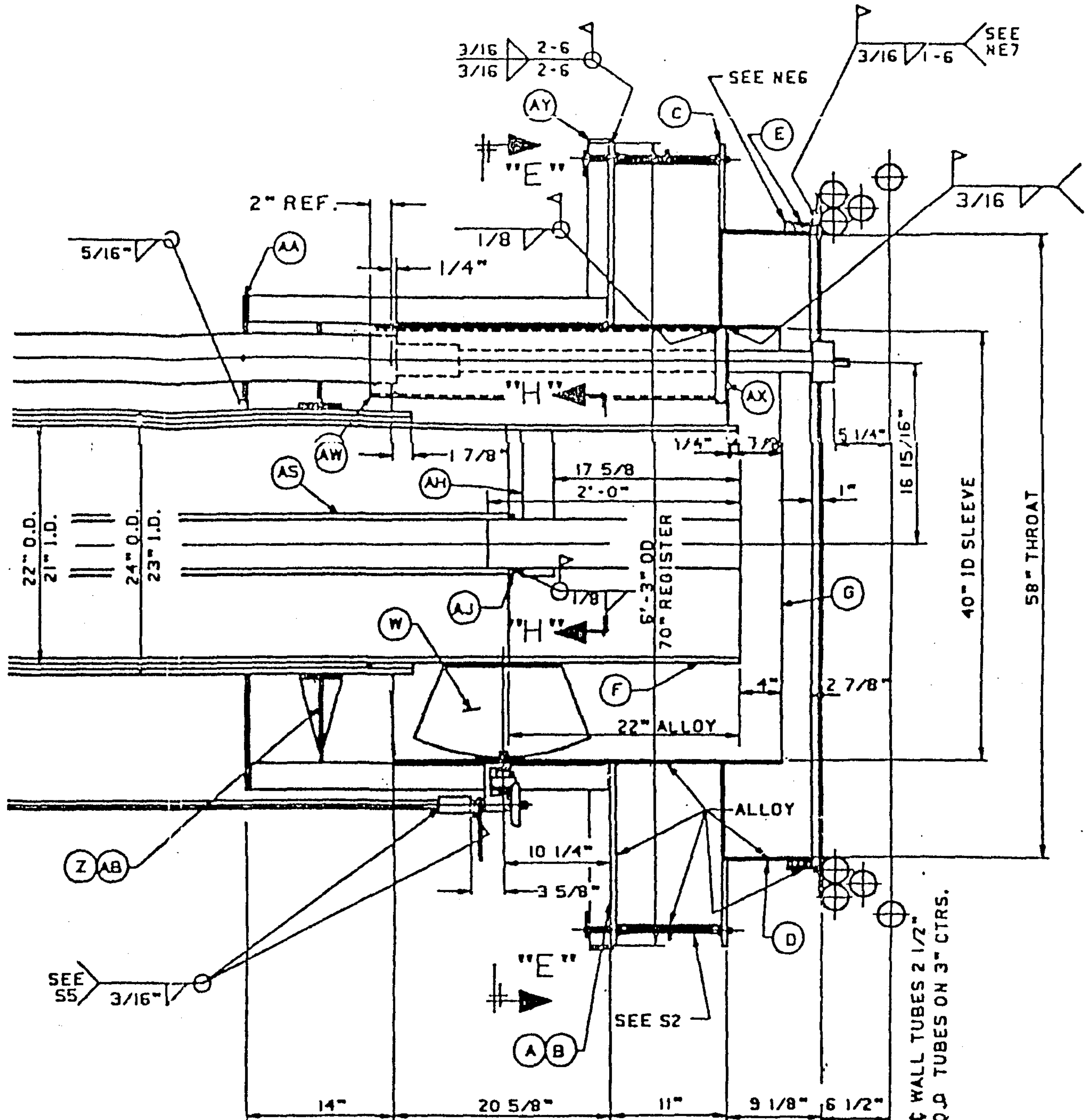

Figure 1 Intermountain Power Project - Existing Design

INTERMOUNTAIN POWER PROJECT
EXISTING DESIGN
(REF. 294361E-12)

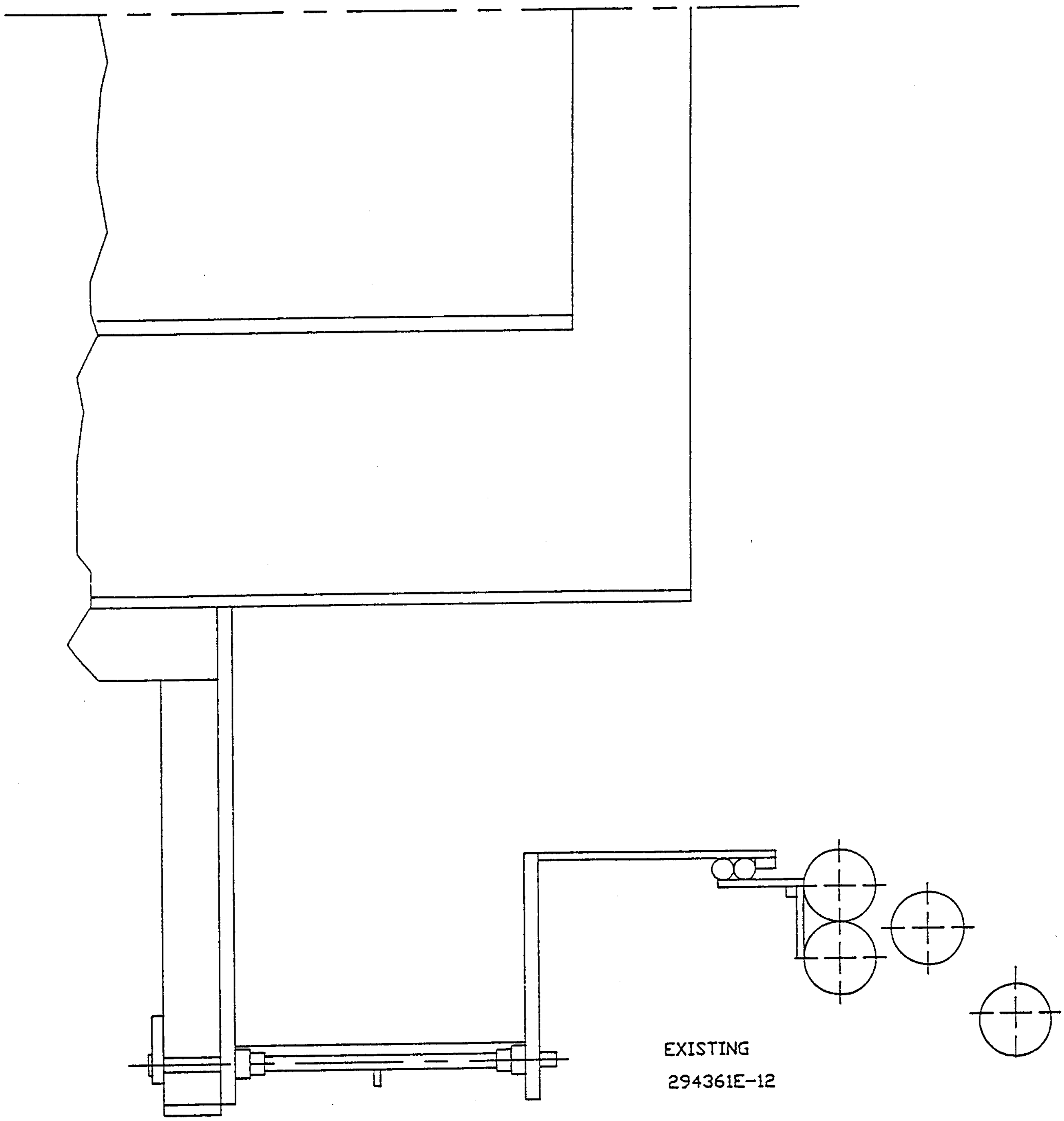

Figure 2 Intermountain Power Project - Existing Design (Expanded view)

INTERMOUNTAIN POWER PROJECT - PROPOSED DESIGN (REF. SK41791E-0)

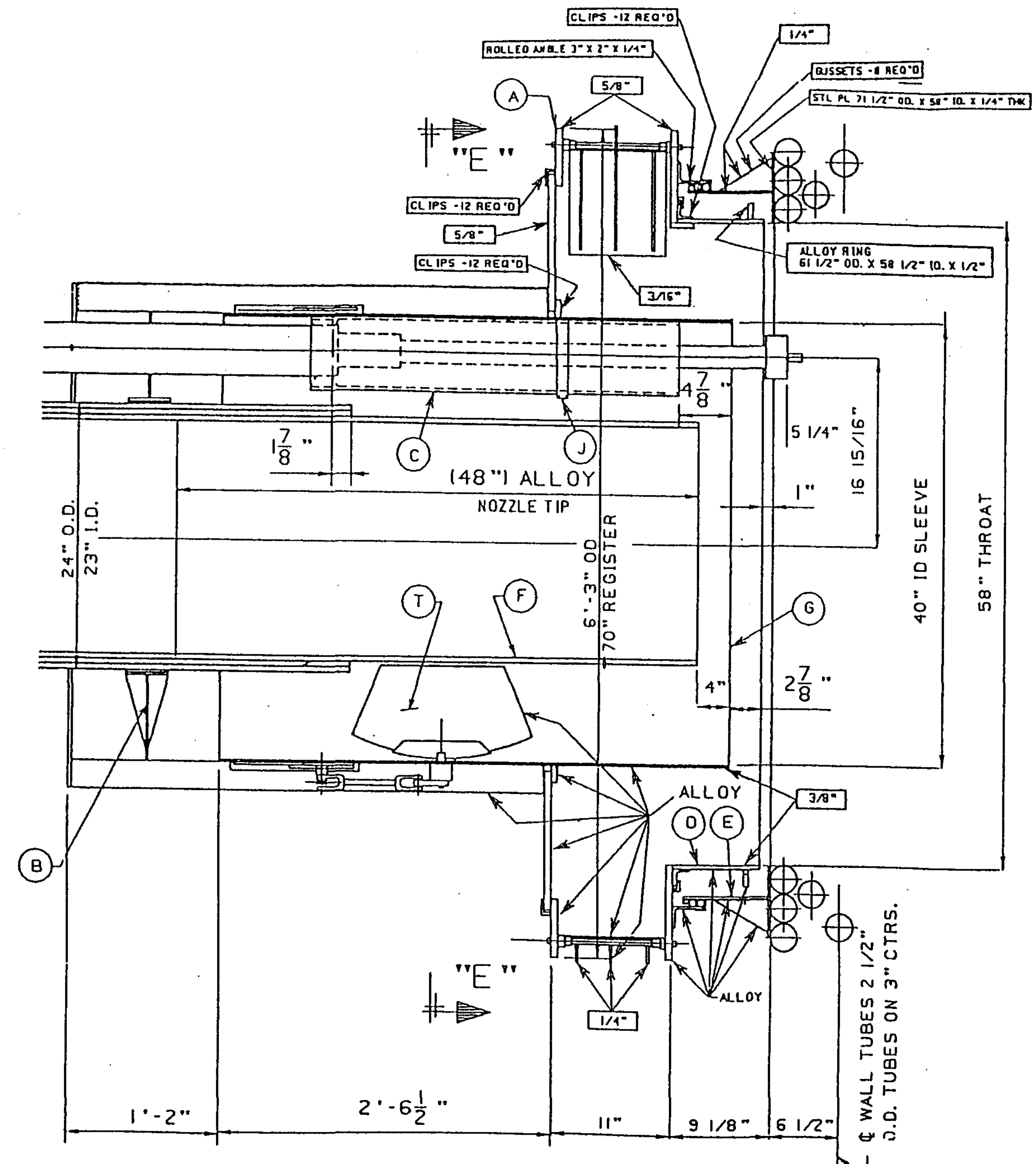

Figure 3 Intermountain Power Project - Proposed Design

INTERMOUNTAIN POWER PROJECT
PROPOSED DESIGN
(REF. SK41791E-0)

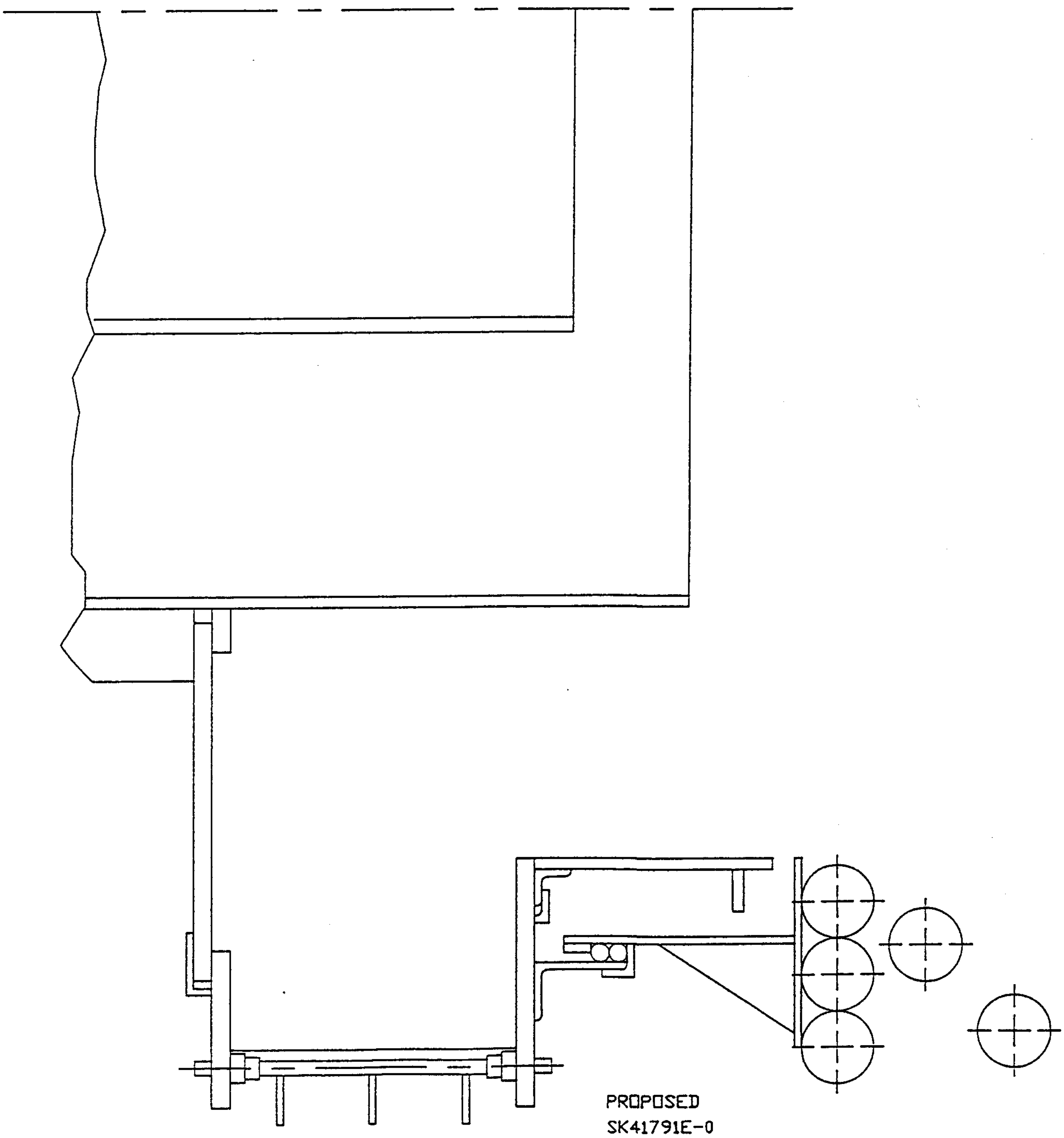

Figure 4 Intermountain Power Project - Proposed Design (Expanded view)

BURNER UPGRADES
PROPOSED MODIFICATIONS SK41791E/0

(REF. RB-614/615 - MAY 1, 1991)

OUTER AIR REGISTER

- o REPLACED WITH MODIFIED HD REGISTER
- o REGISTER FRONT PLATE
  - THICKNESS FROM 1/2" TO 5/8"
  - MATERIAL FROM CARBON STEEL TO 800H
- o REGISTER BACK PLATE
  - THICKNESS FROM 1/2" TO 5/8"
  - MATERIAL FROM TP304 TO 800H
  - SUPPORT LEGS ADDED
  - CENTER SECTION ATTACHED TO FRAME WITH CLIPS (PROVIDES FOR EXPANSION)
- o REGISTER DOOR
  - THICKNESS FROM 10 GA. TO 3/16"
  - ALLOY STIFFENERS ADDED

THROAT SLEEVE

- o THICKNESS FROM 1/4" TO 3/8"
- o MATERIAL FROM TP304 TO 800H
- o EXPANSION RING ADDED TO OD
- o ATTACHED TO FRONT PLATE WITH CLIPS (PROVIDES FOR RADIAL EXPANSION)

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Figure 5 Burner Upgrades-
Proposed Modifications

BURNER UPGRADES
PROPOSED MODIFICATIONS SK41791E/0

(REF. RB-614/615 - MAY 1, 1991)

(CONTINUED)

SLIP SEAL

- o MOVED OUTBOARD ON FRONT PLATE TO ELIMINATE INTERFERENCE WITH EXPANSION OF THROAT SLEEVE
- o SEAL REARRANGED TO MINIMIZE RADIANT HEAT ON ROPE PACKING

INNER AIR SLEEVE

- o THICKNESS FROM 1/4" TO 3/8"
- o MATERIAL FROM TP309 TO 800H
- o MATERIAL OF STIFFENERS FROM CARBON STEEL TO 800H
- o SPIN VANE DRIVE OPERATION CHANGED FROM GEARED TO PUSH/PULL
- o INNER SLEEVE LENGTH INCREASED APPROXIMATELY 10"

COAL NOZZLE

- o ALLOY PORTION OF TIP FROM 33" TO 48"

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Figure 6 Burner Upgrades- Proposed Modifications (continued)

INTERMOUNTAIN POWER PROJECT

RECOMMENDED DESIGN

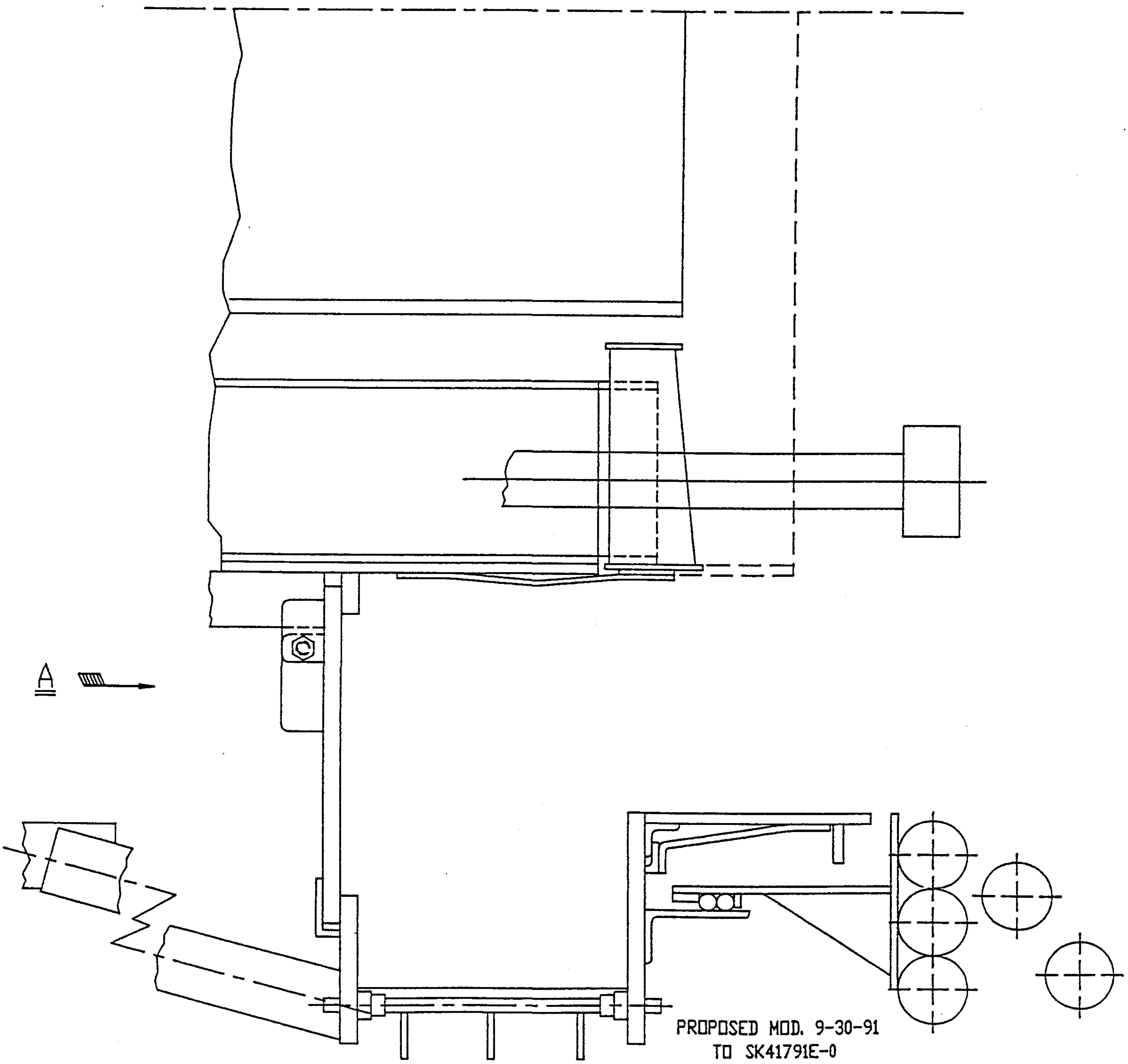

Figure 7 Intermountain Power Project - Recommended Design

EXISTING DESIGN PROBLEMS

COAL PIPE

- o NOZZLE TIP BURNING/WARPING

INNER REGISTER

- o SLEEVE WARPING
- o REGISTER VANE JAMMING

OUTER REGISTER

- o BACK PLATE WARPING
- o THROAT INTERACTION WITH AIR SEAL
- o REGISTER VANE JAMMING

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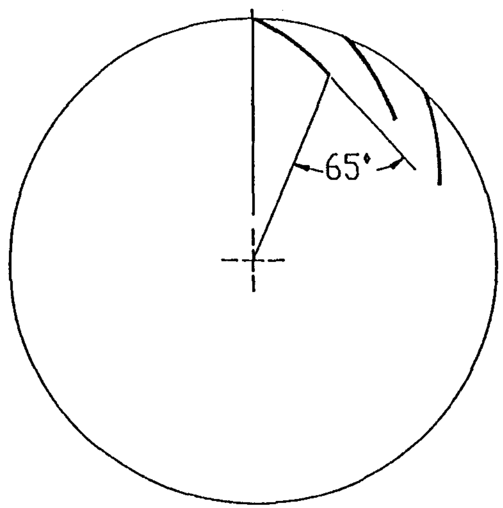
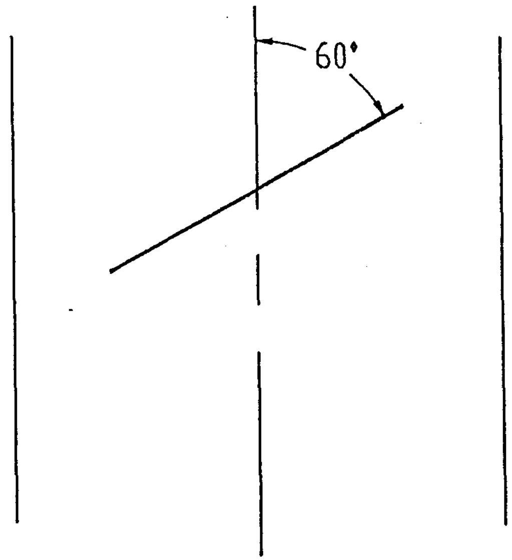
Figure 8 Existing Design Problems

AIR REGISTERS

- o OPERATING CONDITIONS
  - 100 PERCENT LOAD WITH 42 BURNERS
  - AIR TEMPERATURE = 650°F
  - WINDBOX TO FURNACE DIFFERENTIAL PRESSURE = 2.0 INCHES WATER
- o SETTINGS (REF. NOVEMBER 24, 1988)



OUTER REGISTER VANE
EXIT FLOW ANGLE (OFF RADIAL)



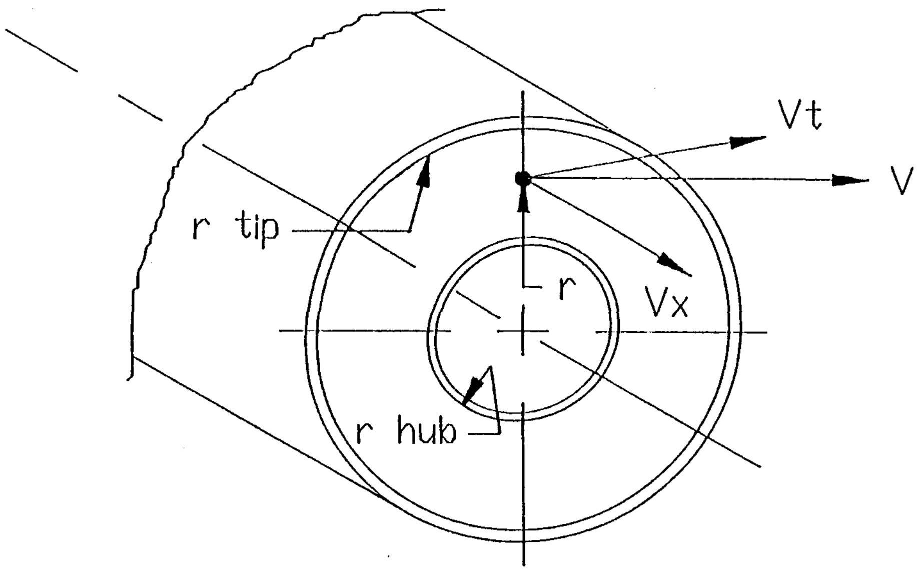
INNER SPIN VANE
EXIT FLOW ANGLE (OFF AXIAL)

IPP.AR

Figure 9 Air Registers

SWIRL NUMBER

- o MEASURE OF JET TANGENTIAL TO AXIAL MOMENTUM
- o DETERMINES SIZE OF COMBUSTION INTERNAL RECIRCULATION ZONE



$$\text{Local Swirl No.} = \frac{rV_t}{V_x \, r_{tip}}$$

$$\text{Integrated Swirl No.} = \frac{1}{r_{tip}} \frac{\int_{r_{hub}}^{r_{tip}} rV_t \; (\rho V_x \; 2\pi r)\,dr}{\int_{r_{hub}}^{r_{tip}} V_x \; (\rho V_x \; 2\pi r)\,dr}$$

IPP.SN(COR)

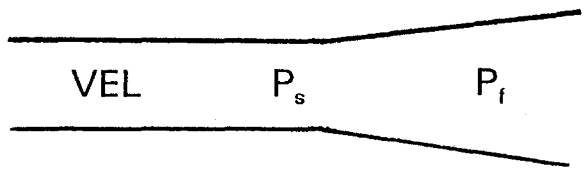
Figure 10 Swirl Number

IP7_004626

RECIRCULATION PARAMETER

- MEASURE OF AXIAL MOMENTUM TO OVERCOME LOCAL STATIC PRESSURE TO FURNACE PRESSURE RISE

- POTENTIAL FOR RECIRCULATION EXISTS WHEN THE PARAMETER IS A NEGATIVE VALUE



$(P_s < P_f)$

RECIRCULATION PARAMETER = [(AXIAL MOMENTUM / UNIT AREA) - PRESSURE RISE]

$$\text{RECIRCULATION PARAMETER} = [(\rho V^2 / g_c) - (P_f - P_s)]$$

IPP.RP

Figure 11 Recirculation Parameter

INTER MOUNTAIN POWER PROJECT - UNITS 1 & 2

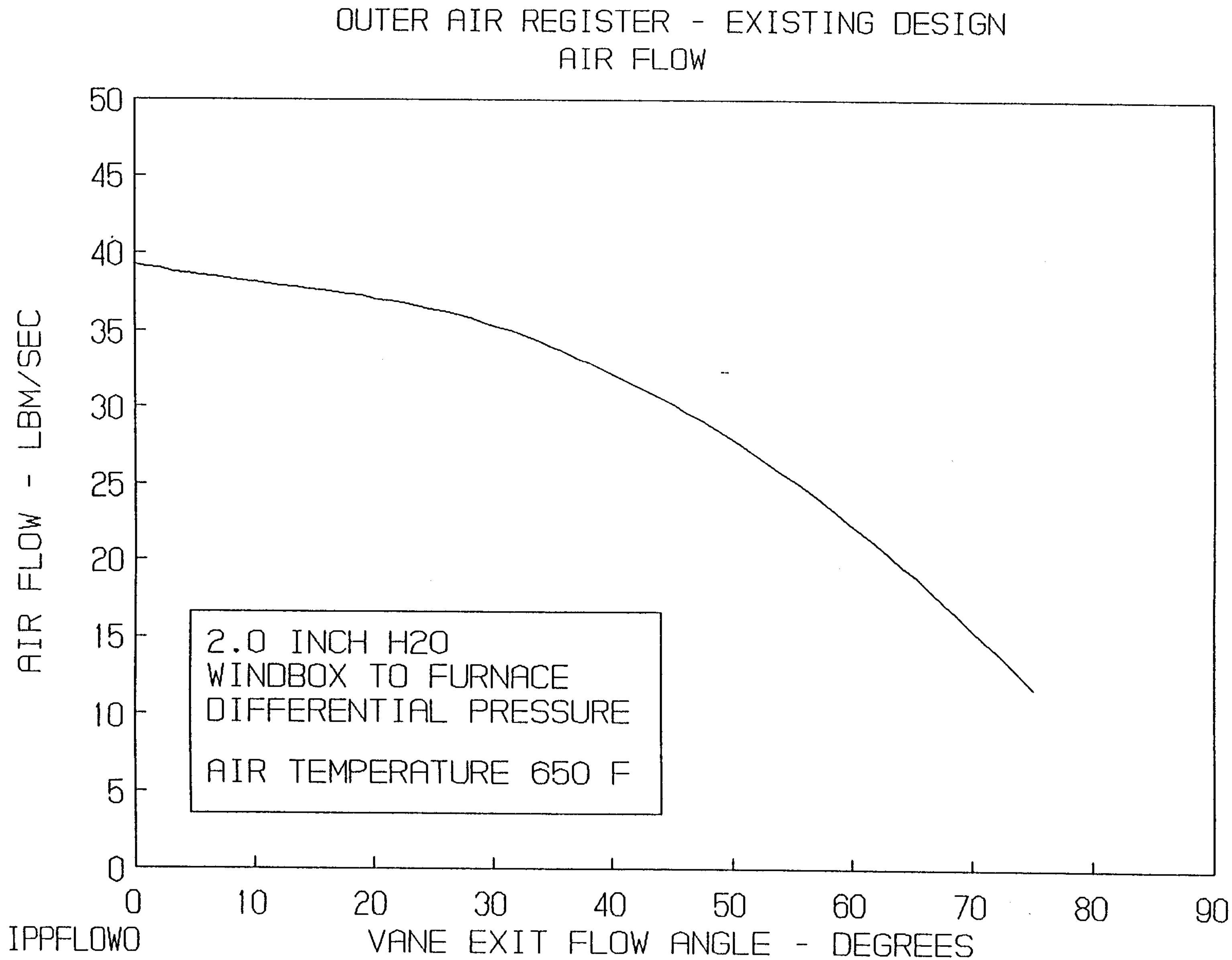


Figure 12 Outer Air Register-
Existing Design Air Flow

IP7_004628

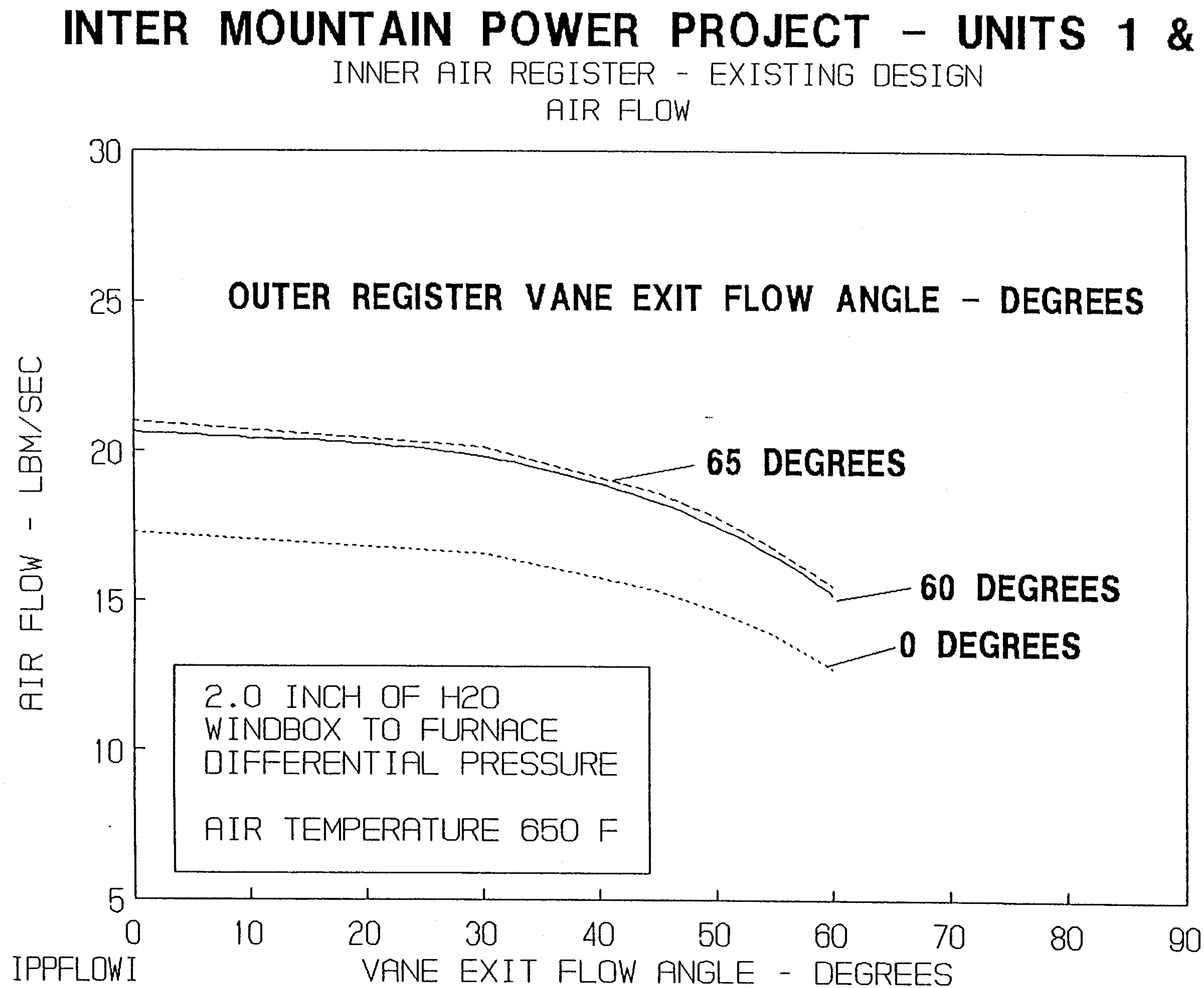


Figure 13 Inner Air Register-
Existing Design Air Flow

IP7_004629

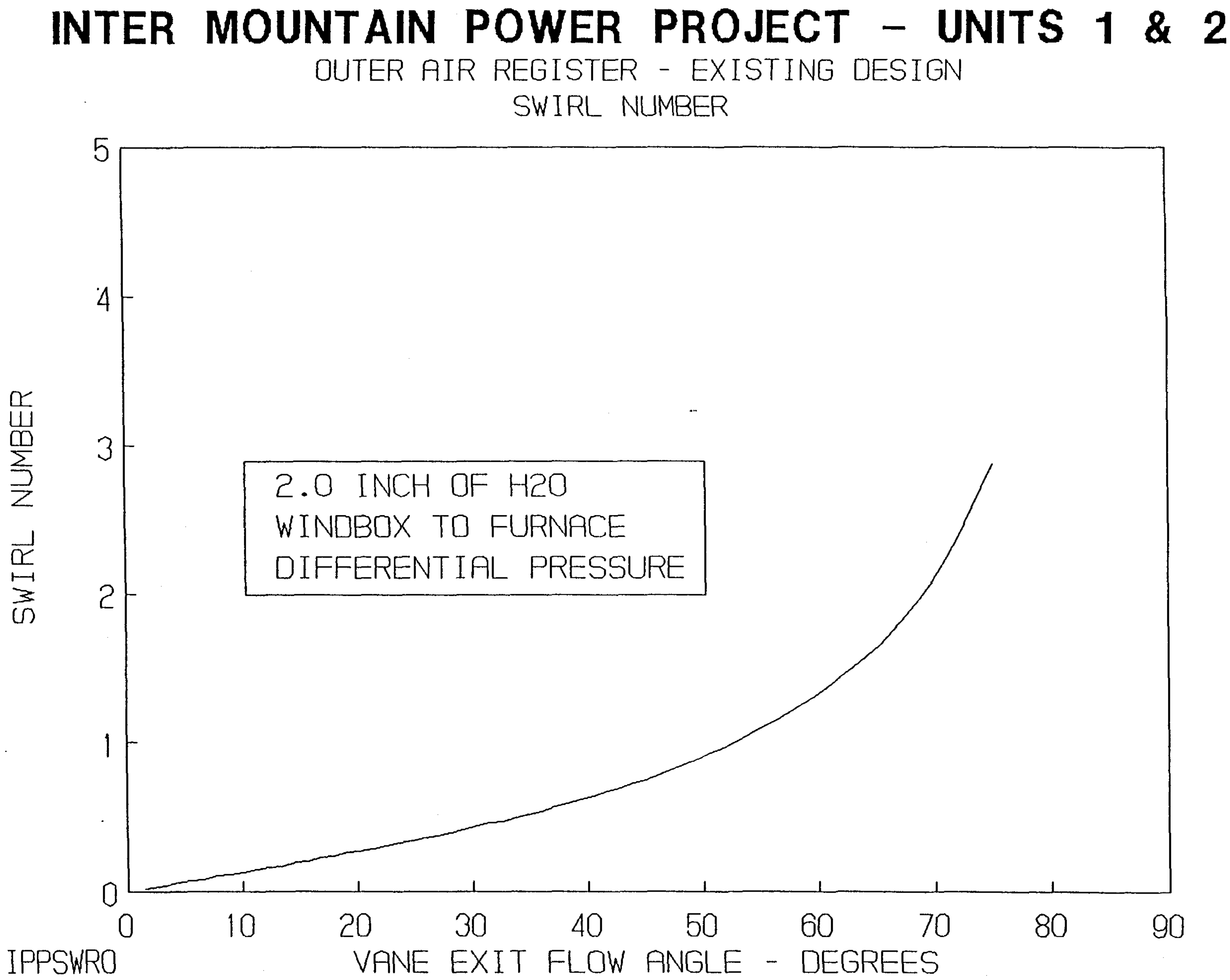


Figure 14 Outer Air Register- Existing Design Swirl Number

IP7_004630

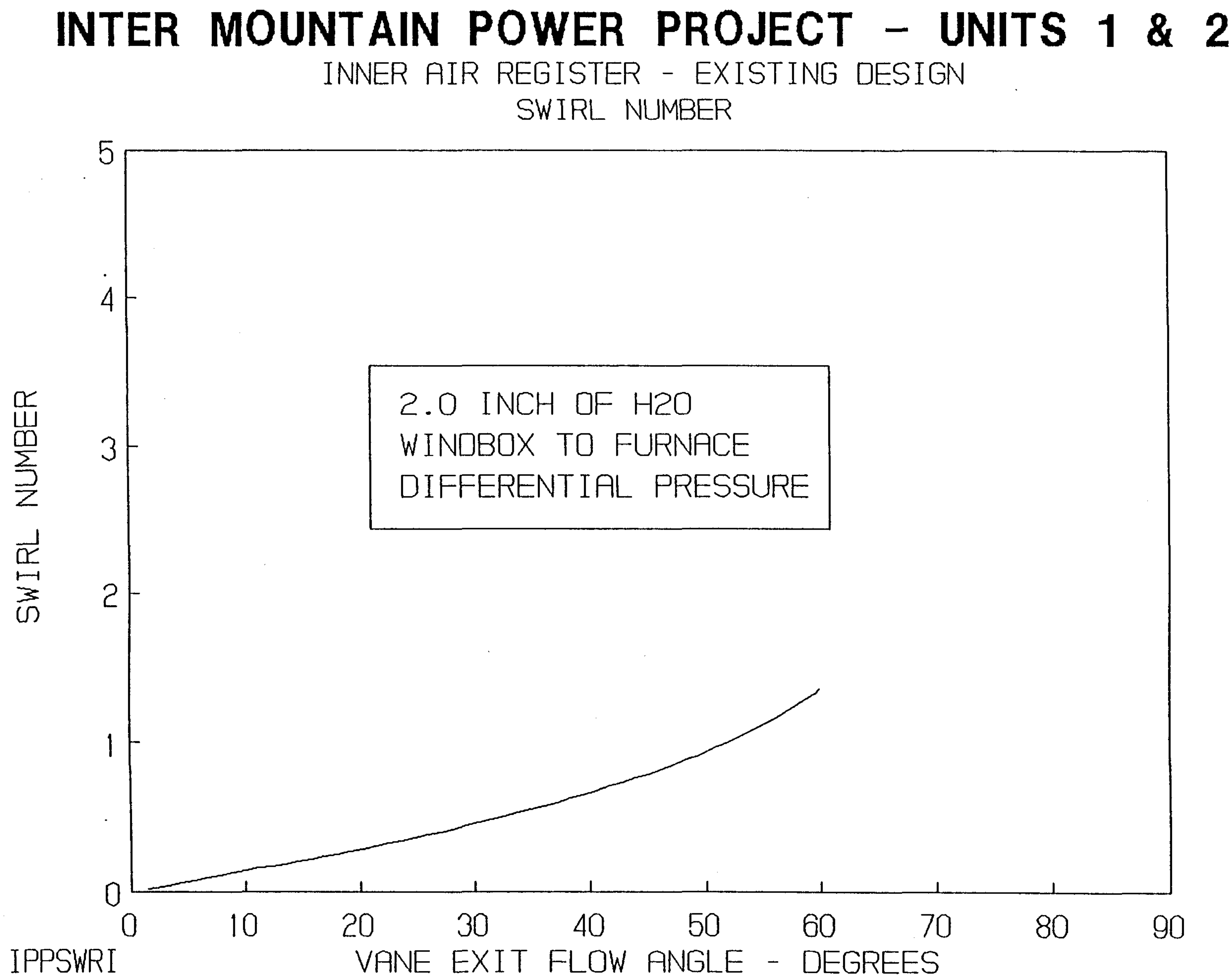


Figure 15 Inner Air Register- Existing Design Swirl Number

IP7_004631

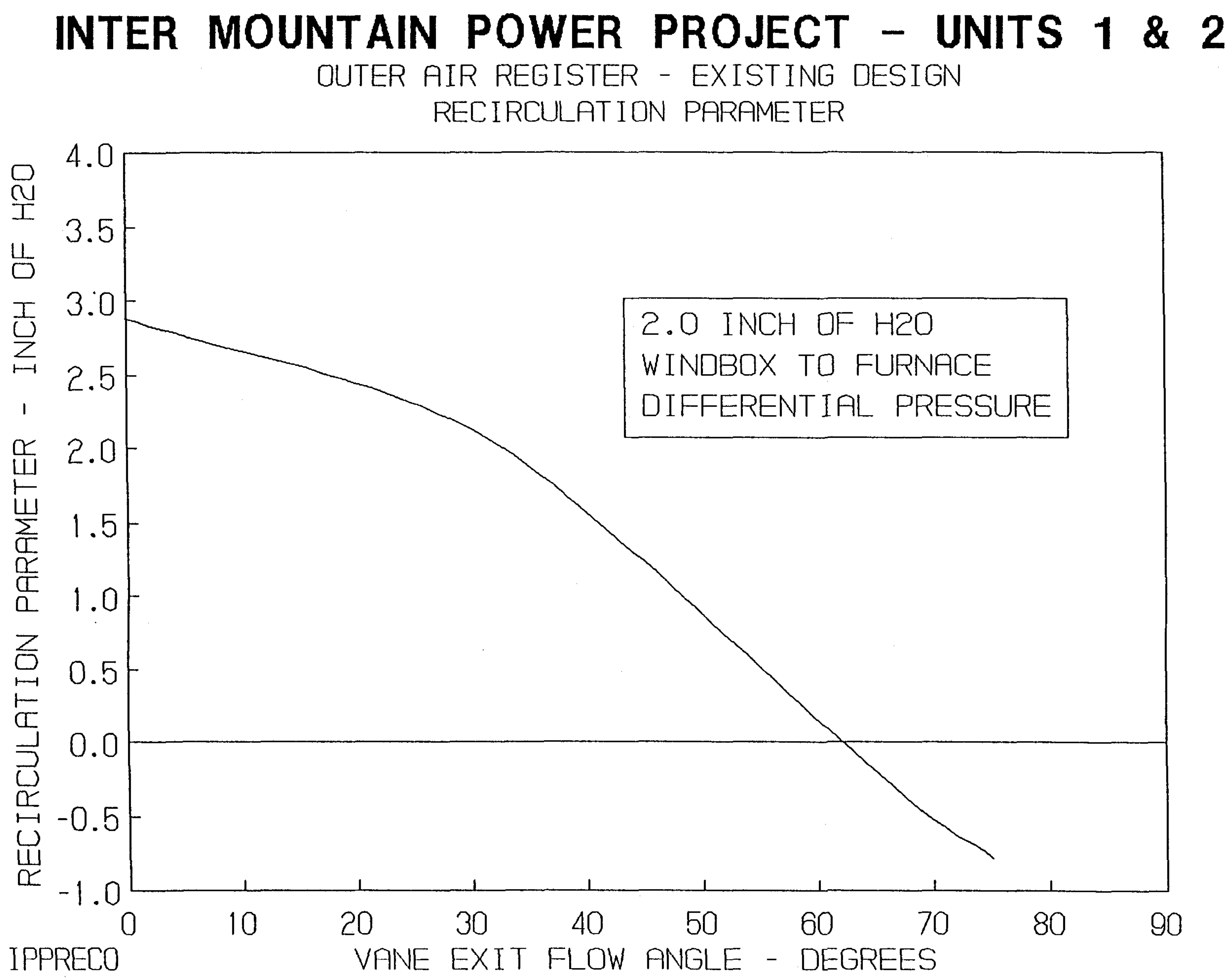


Figure 16 Outer Air Register-
Existing Design
Recirculation Parameter

IP7_004632

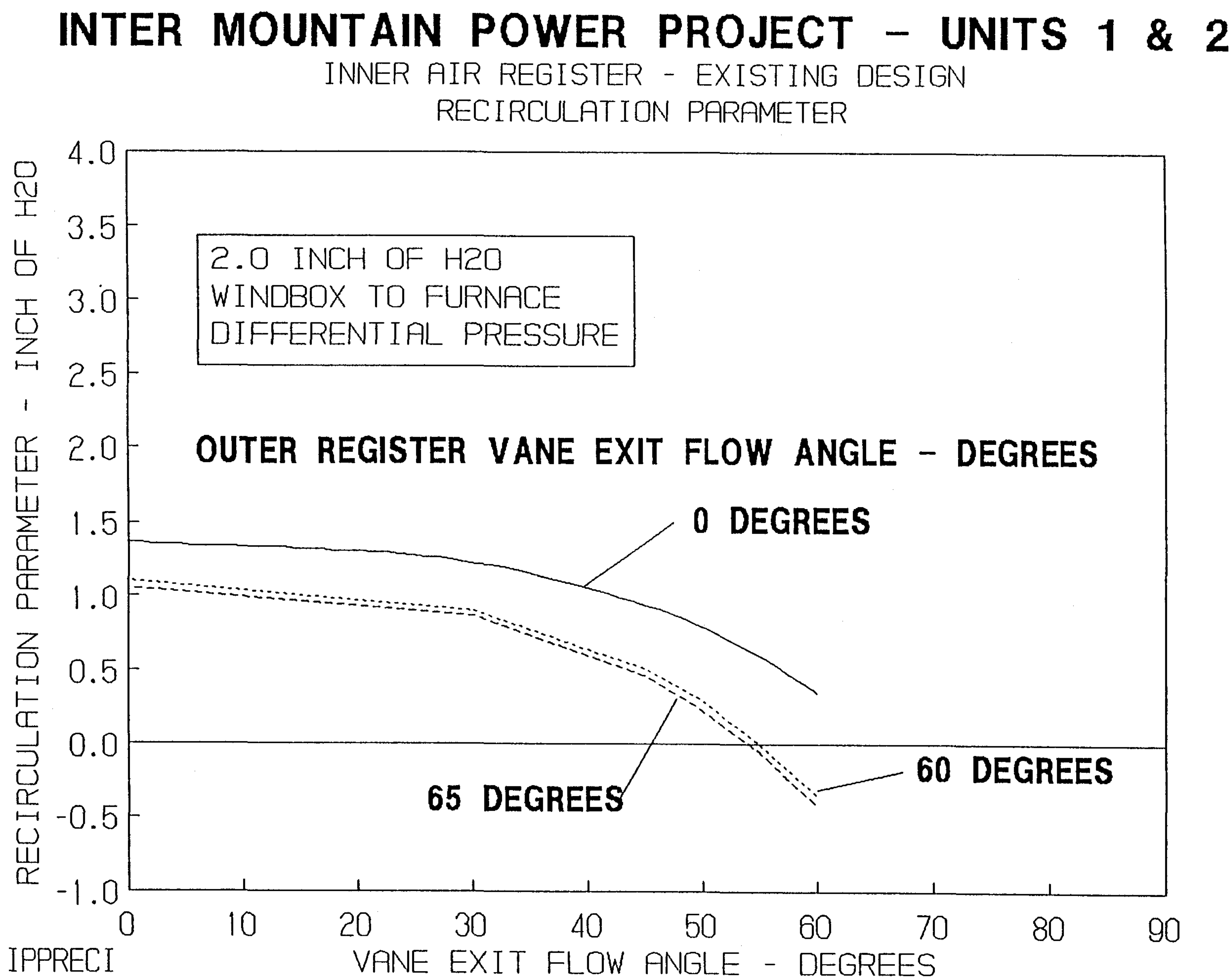


Figure 17 Inner Air Register-
Existing Design
Recirculation Parameter

IP7_004633

BURNER - UNIT 2

(REF. RB-0615 - NOVEMBER 24, 1988)

BURNER MODIFICATIONS

- o EXPANSION JOINTS WERE INSTALLED ON THE OUTER REGISTER DRIVE HANDLES
- o BACKPLATES AMD FRONT PLATES OF REGISTERS WERE CUT FREE AND EXPANSION CLIPS WERE INSTALLED

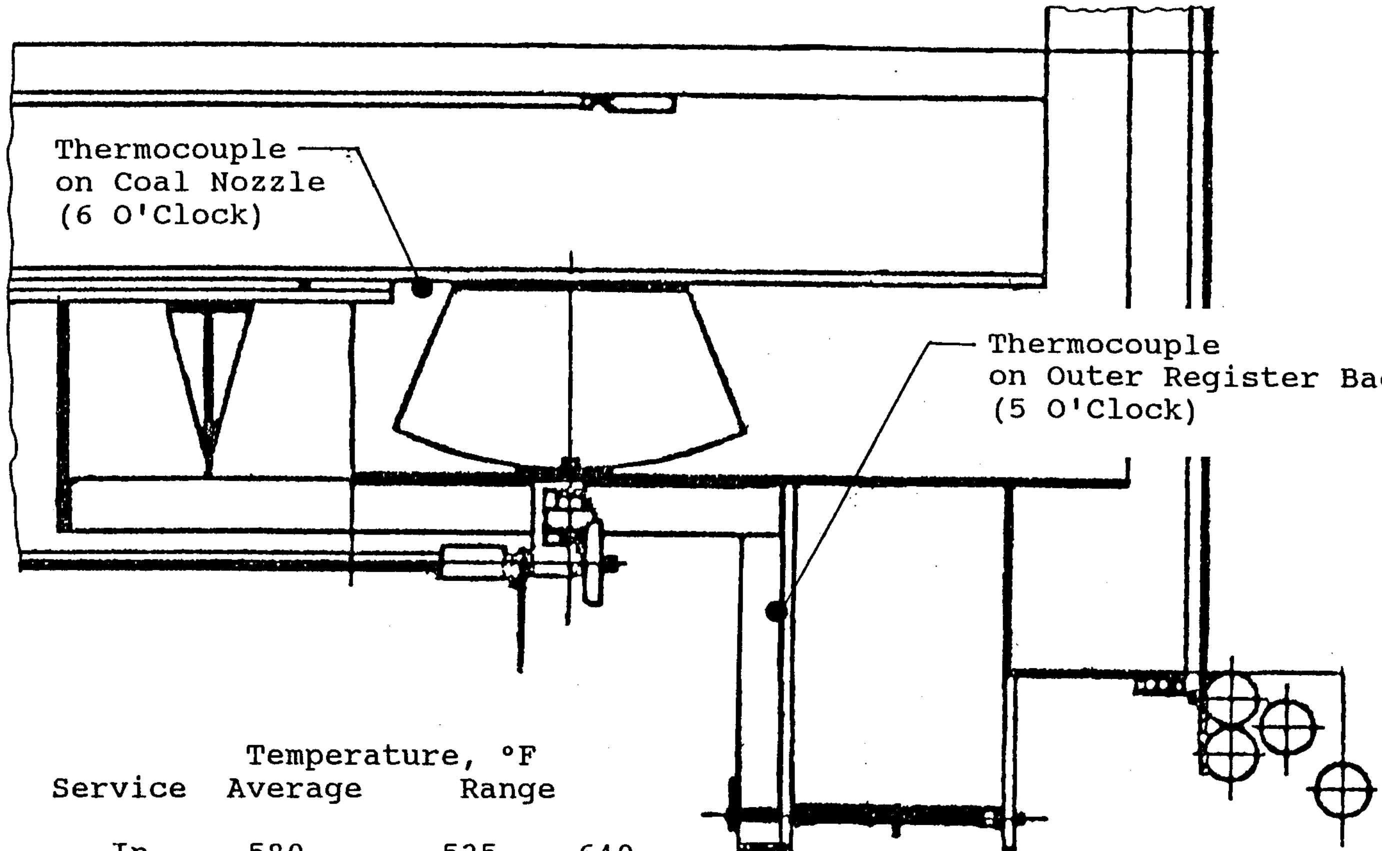
BURNER SETTINGS

- o OUTER REGISTERS - 6" (DOOR STIFFENER TO DOOR - ON A PERPENDICULAR)
- o SPIN VANES - 30° (WHERE 90° IS STRAIGHT THROUGH, 0° IS CLOSED)
- o BACK PLATES - 5", 4", 3", 3", 4", 5" OPEN
- o (ALL BURNER SETTINGS HAVE BEEN LOCKED IN PLACE)

IPP.BS

Figure 18 Burner - Unit 2
(November 24, 1988)

MEASURED TEMPERATURES AT FULL LOAD
(AUGUST 30, 1991)



	Service	Temperature, °F Average	Range	
Coal Nozzle	In	580	525 - 640	
	Out	980	830 - 1200	
Outer Register (Back Side)	In	1000	850 - 1220	
	Out	1175	980 - 1285	(1450°F MAX)

Figure 19 Measured Temperatures at Full Load (August 30, 1991)

IP7_004635

INTERMOUNTAIN POWER PROJECT
HEAT TRANSFER ANALYSIS

IN SERVICE

- o CONVECTIVE COOLING FROM 100 PERCENT LOAD REGISTER AIRFLOW
- o FLAME RADIATION PRIMARILY ON BACK WALL
- o BACK PLATE TEMPERATURE: 1,050°F (ANALYSIS) VS. 1,000°F AVG (THERMOCOUPLE)

OUT OF SERVICE

- o CONVECTIVE COOLING TO 20 PERCENT AIRFLOW
- o RADIATION LOAD SAME AS IN SERVICE FOR WORST CASE ANALYSIS
- o ACTUAL RADIATION IS LESS WITH BURNER FLAME OUT
- o PREDICTED BACK PLATE TEMPERATURE HIGHER THAN MEASURED

IPPHTA

Figure 20 Heat Transfer Analysis Design Conditions

FINITE ELEMENT MODEL: EXISTING DESIGN

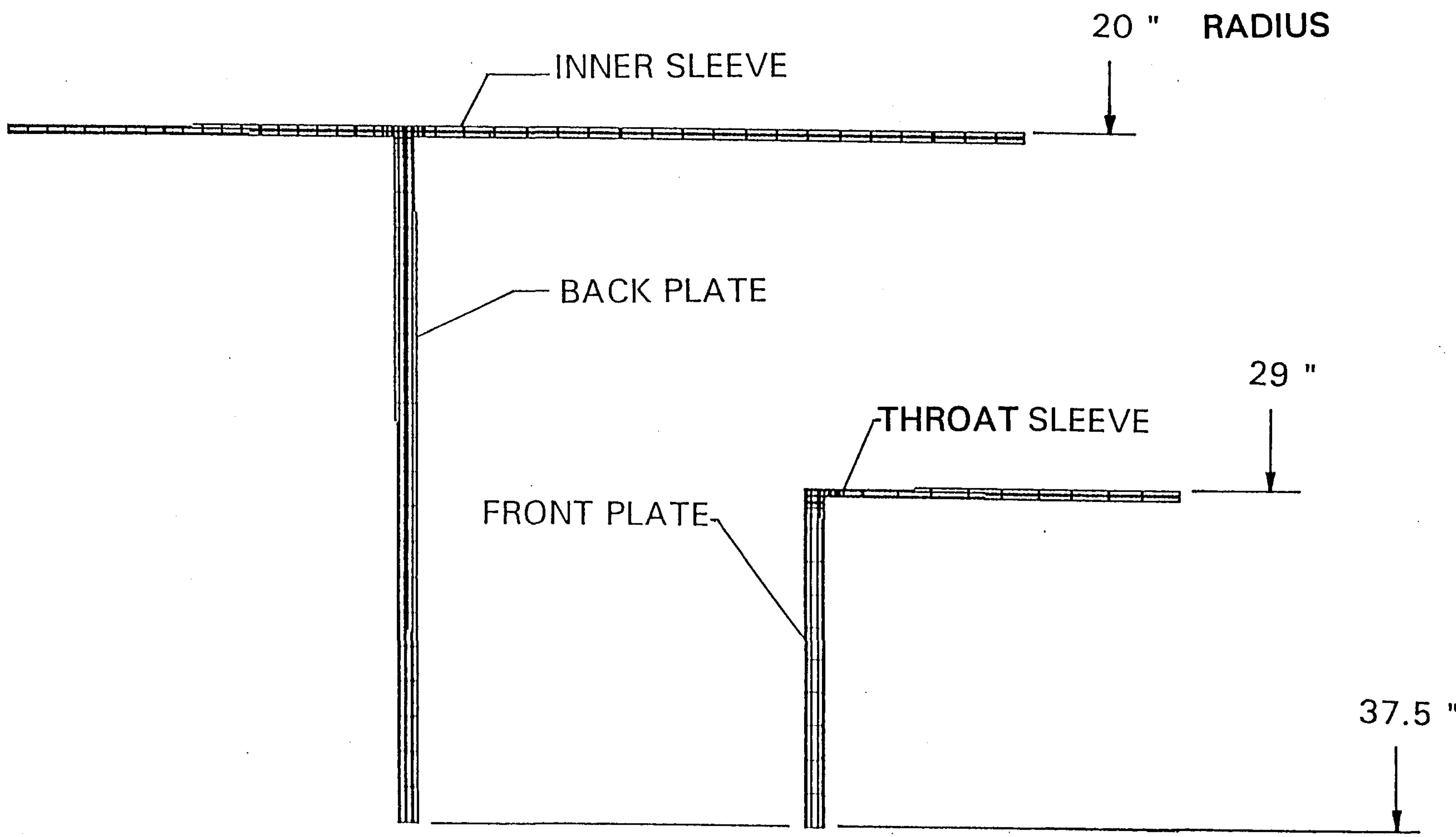


Figure 21 Finite Element Model:
Existing Design

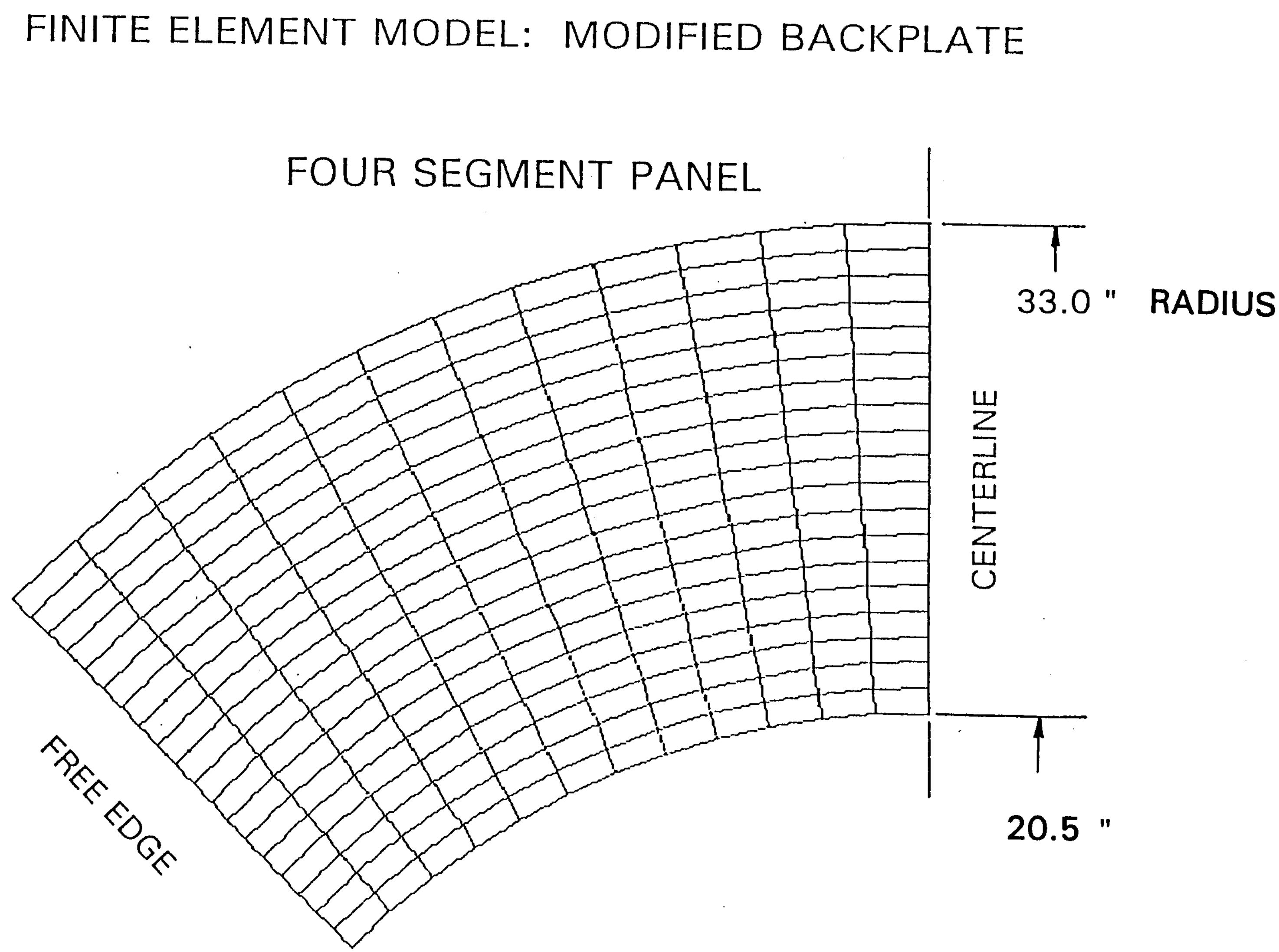


Figure 22 Finite Element Model:
Modified Backplate

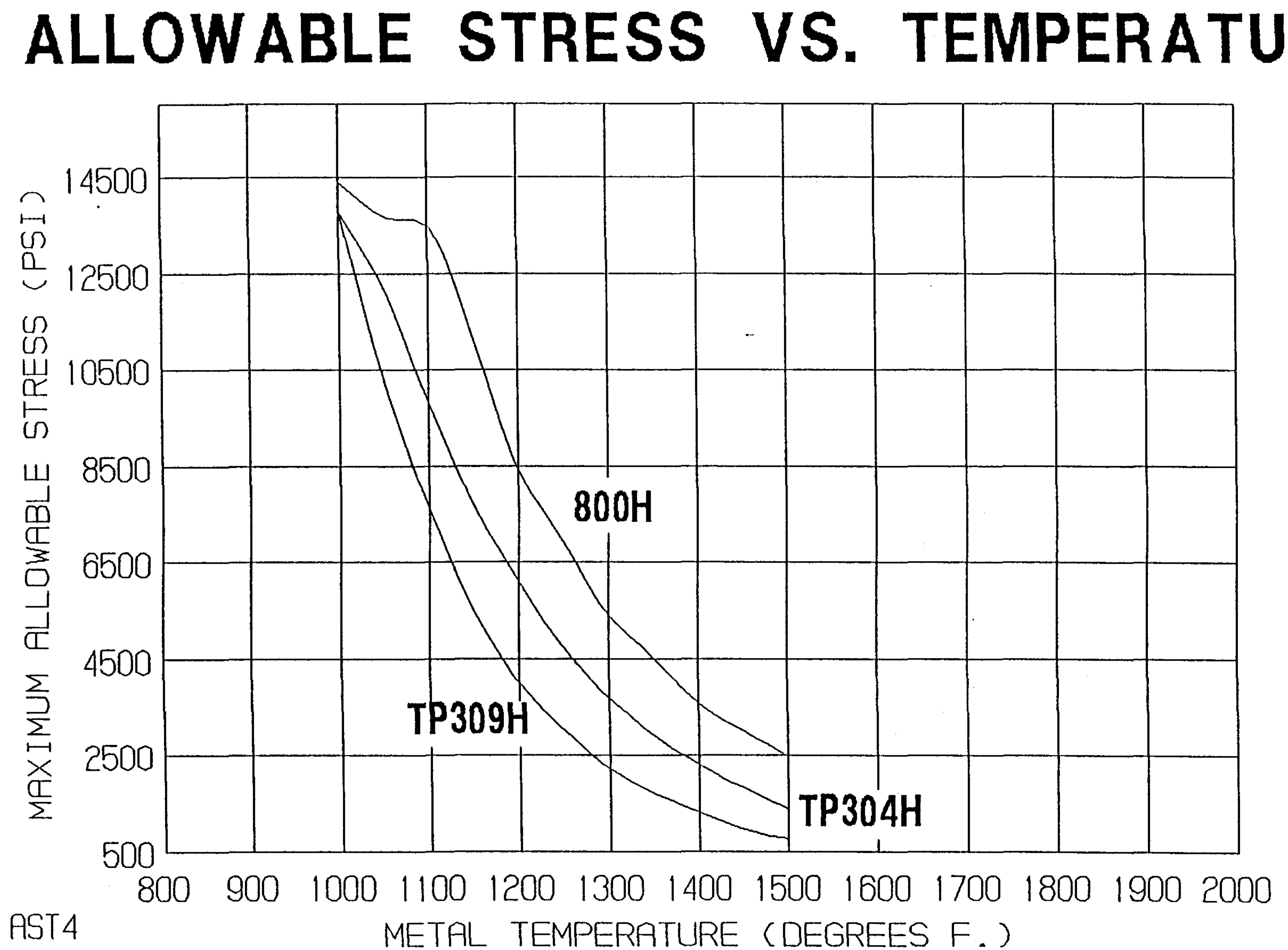


Figure 23 Allowable Stress vs. Temperature

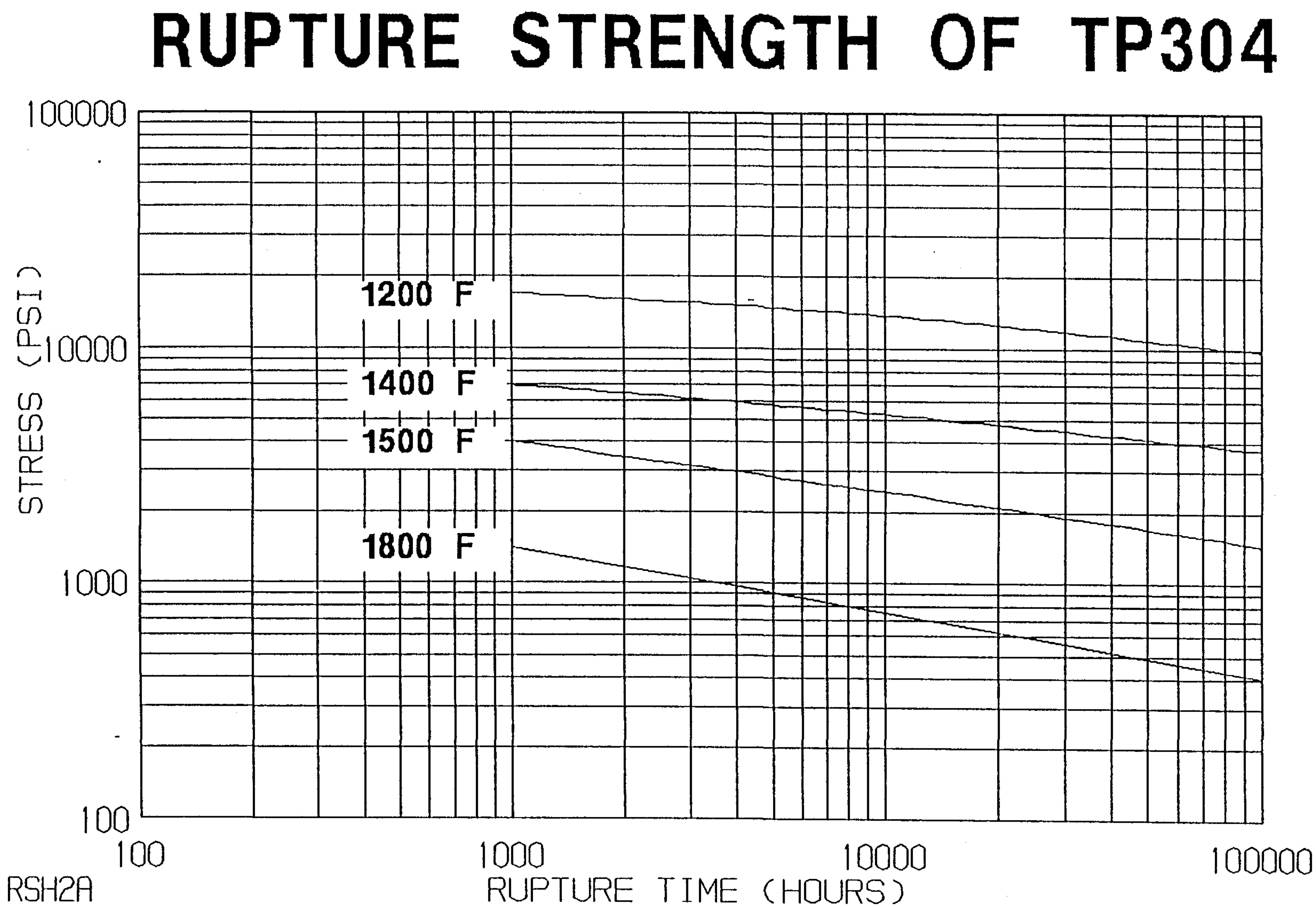


Figure 24 Rupture Strength of TP304

RUPTURE STRENGTH OF TP309

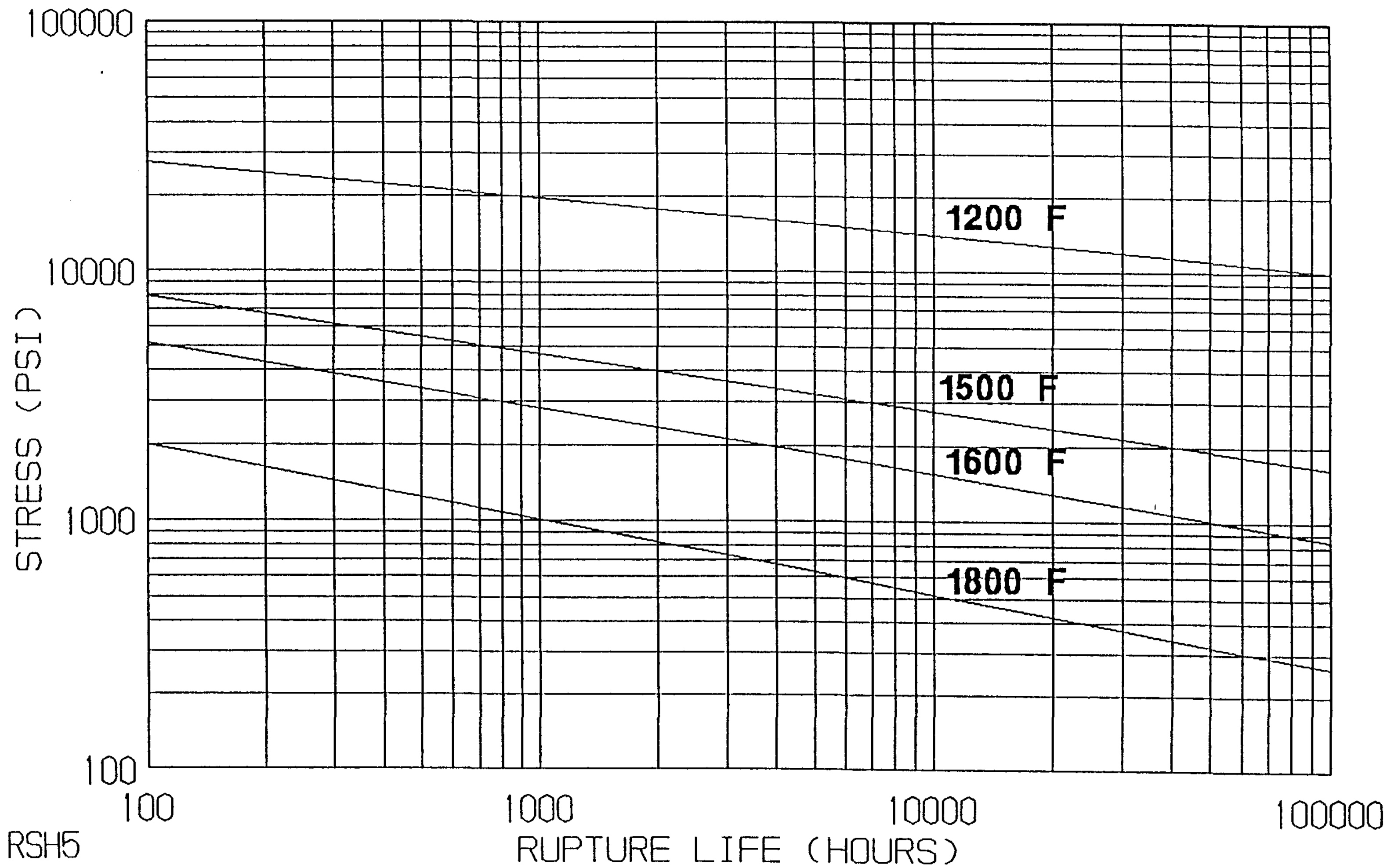


Figure 25 Rupture Strength of TP309

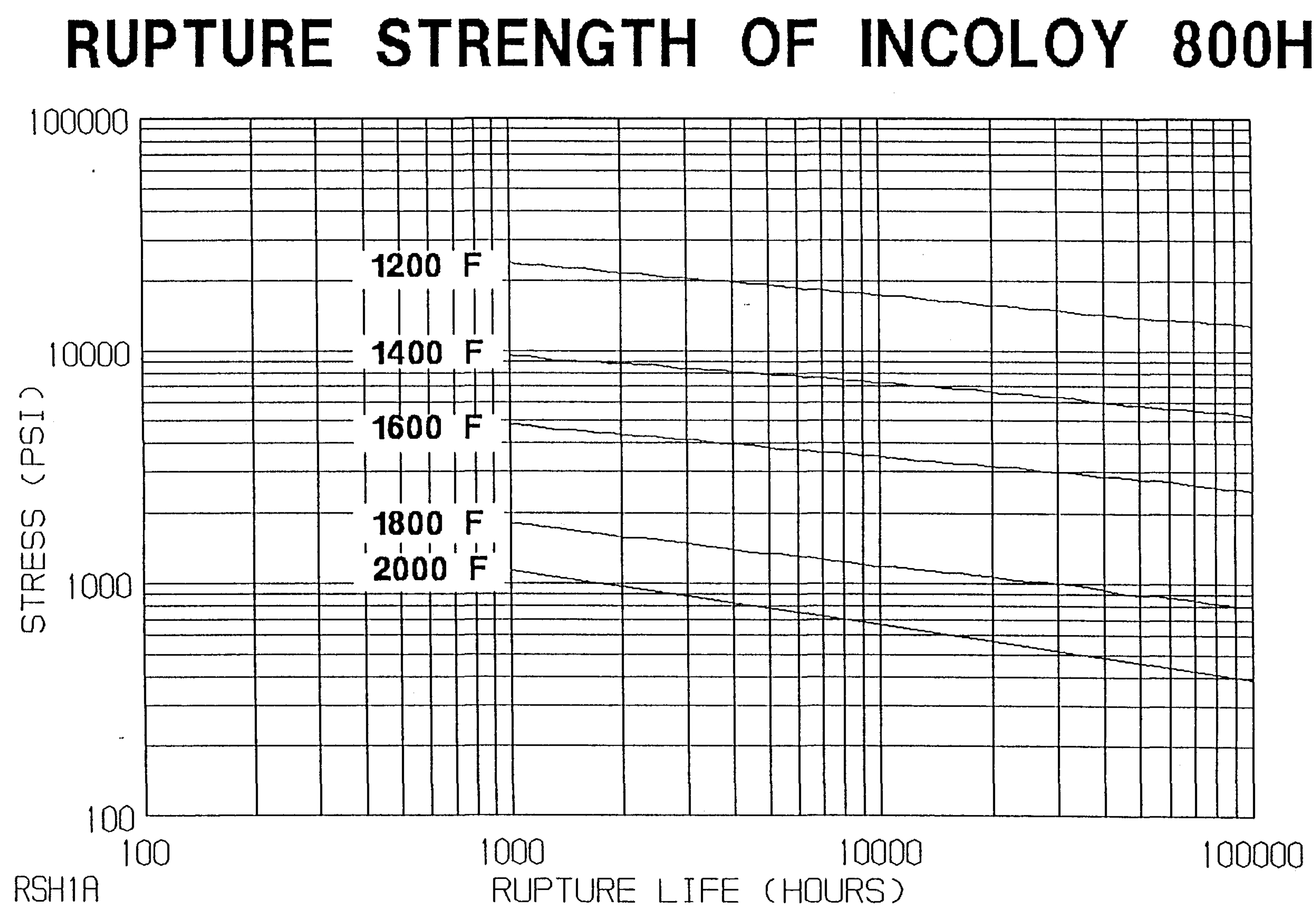
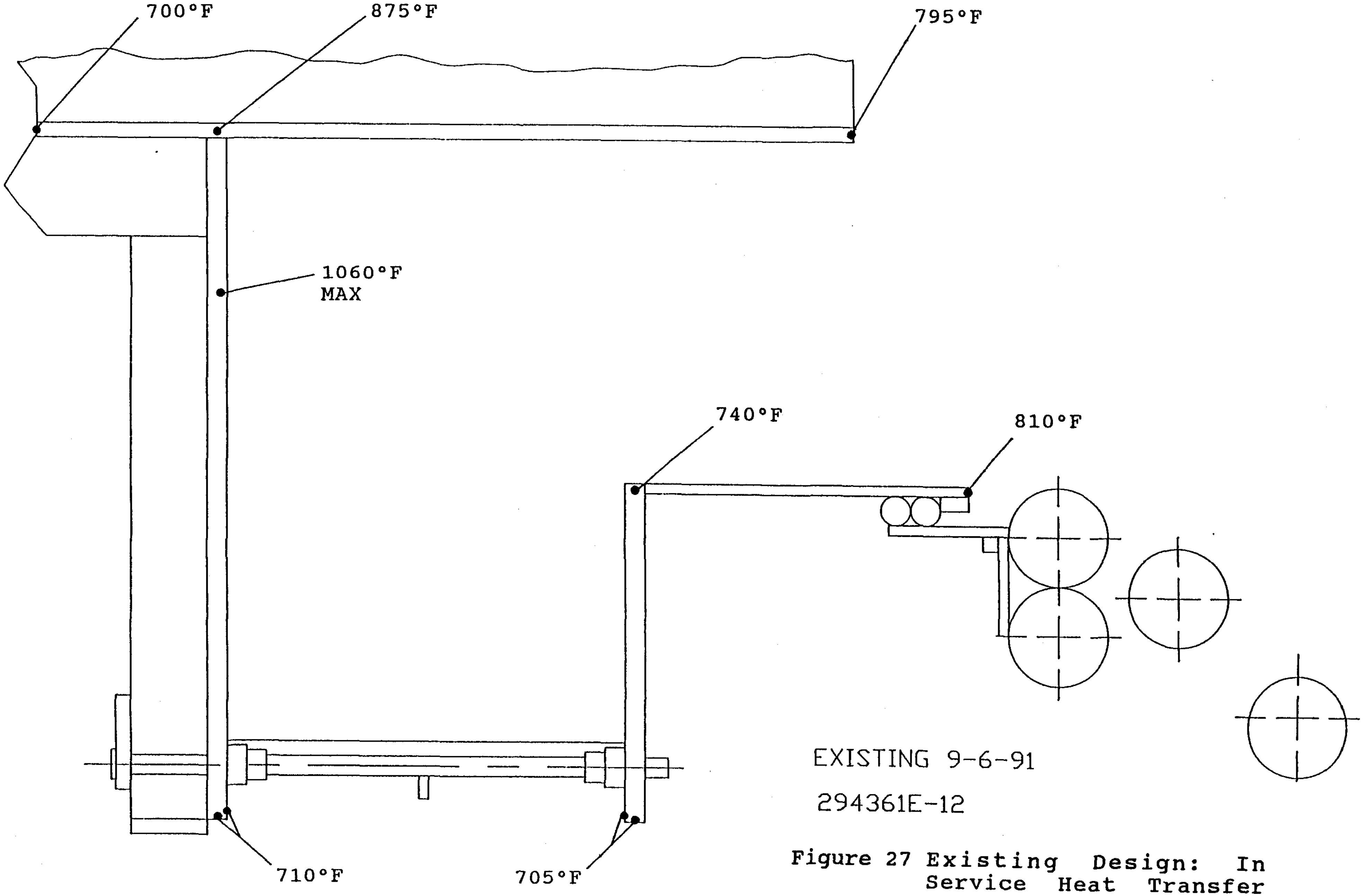


Figure 26 Rupture Strength of Incoloy 800 HT

INTERMOUNTAIN POWER PROJECT
EXISTING DESIGN : IN SERVICE
HEAT TRANSFER ANALYSIS



EXISTING 9-6-91

294361E-12

Figure 27 Existing Design: In Service Heat Transfer Analysis

IP7_004643

INTERMOUNTAIN POWER PROJECT
EXISTING DESIGN: IN SERVICE
FINITE ELEMENT MODEL:
DEFORMATION ANALYSIS

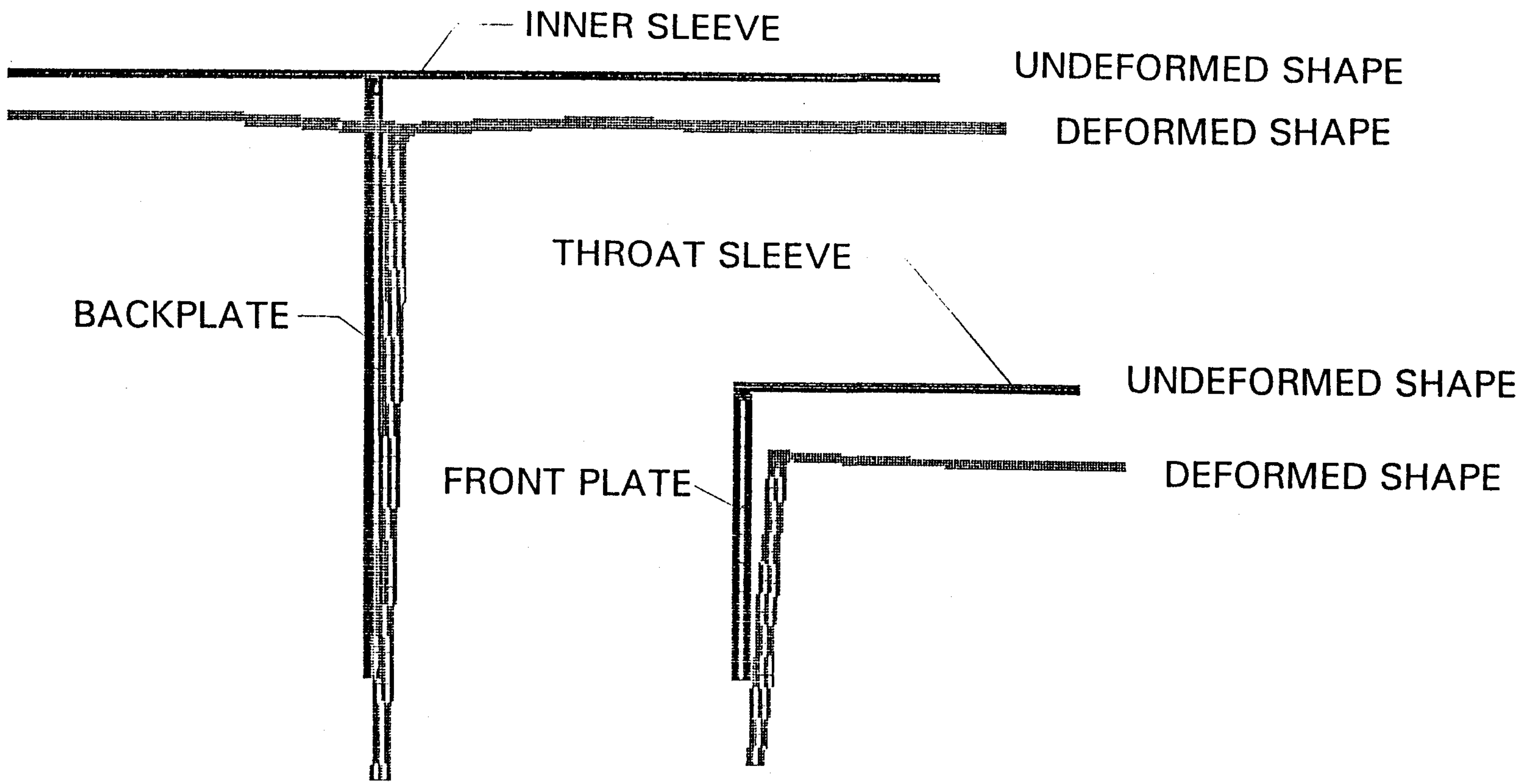


Figure 27A Existing Design: In Service Deformation Analysis

IP7_004644

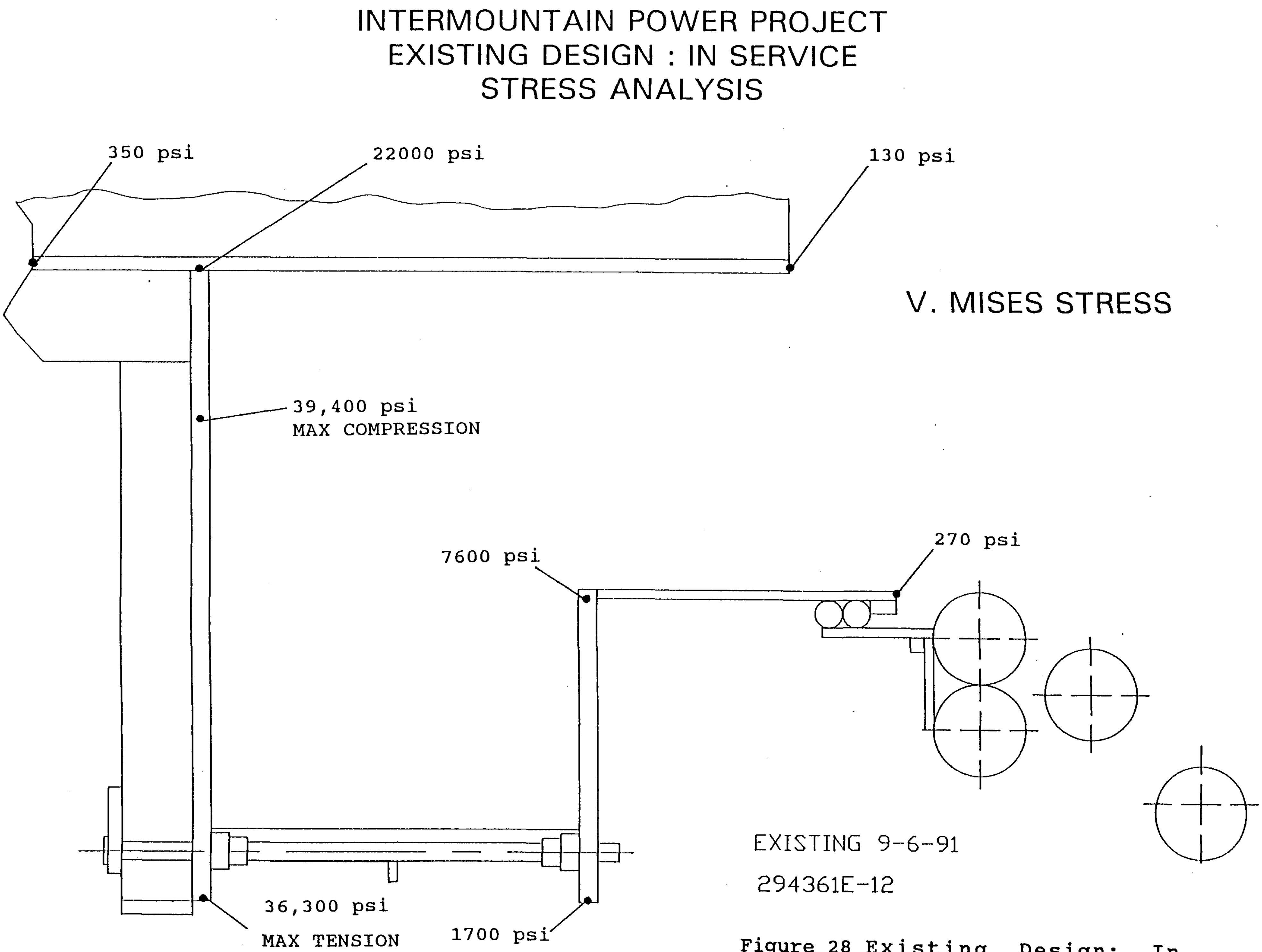


Figure 28 Existing Design: In Service Stress Analysis

IP7_004645

SUMMARY

EXISTING DESIGN (REF. 294361-12)
IN SERVICE

BACK PLATE

- o HOT SPOT ON BACK PLATE OUTBOARD OF INNER SLEEVE WITHIN RANGE OF MEASURED TEMPERATURES
- o HIGH RADIAL TEMPERATURE GRADIENT CAUSES HIGH TANGENTIAL STRESS GRADIENT
- o SEPARATION FROM SLEEVE PREDICTED WITH SUBSEQUENT CONING/BUCKLING

INNER SLEEVE

- o LOW TEMPERATURE AND STRESSES EXCEPT FOR LOCAL STRESS CONCENTRATION AT BACK PLATE ATTACHMENT
- o TEMPERATURE/STRESS RELIEF WILL OCCUR FOLLOWING SEPARATION OF BACK PLATE

FRONT PLATE & THROAT SLEEVE

- o LOW TEMPERATURE AND STRESSES EXCEPT FOR LOCAL STRESS CONCENTRATION AT JOINT
- o PREDICTED PEAK STRESS AT JOINT WITHIN ALLOWABLE LIMITS

IPPSUM1

Figure 29 Summary Existing Design:
In Service

INTERMOUNTAIN POWER PROJECT
EXISTING DESIGN : OUT OF SERVICE
HEAT TRANSFER ANALYSIS

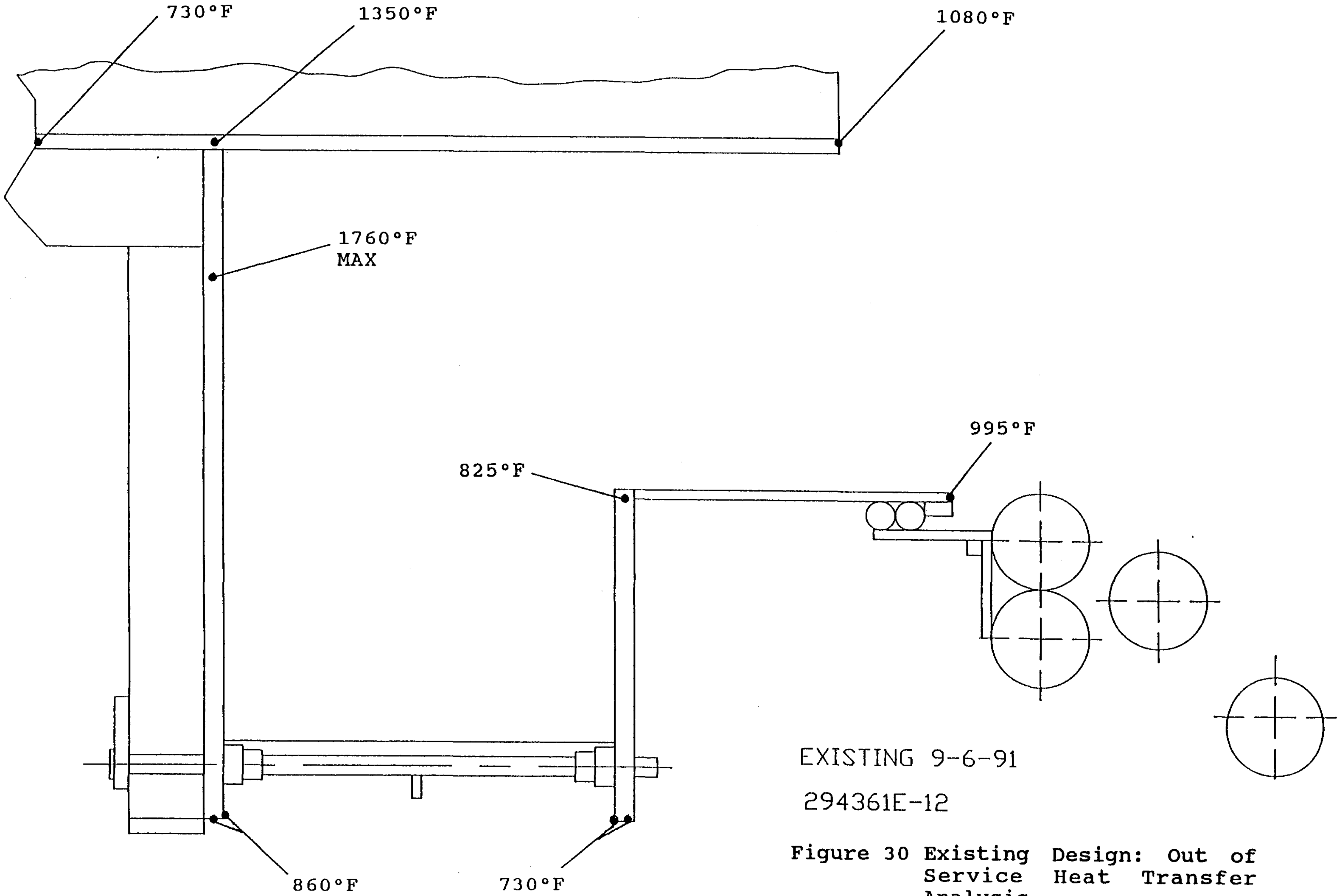


Figure 30 Existing Design: Out of Service Heat Transfer Analysis

IP7_004647

INTERMOUNTAIN POWER PROJECT
EXISTING DESIGN : OUT OF SERVICE
STRESS ANALYSIS

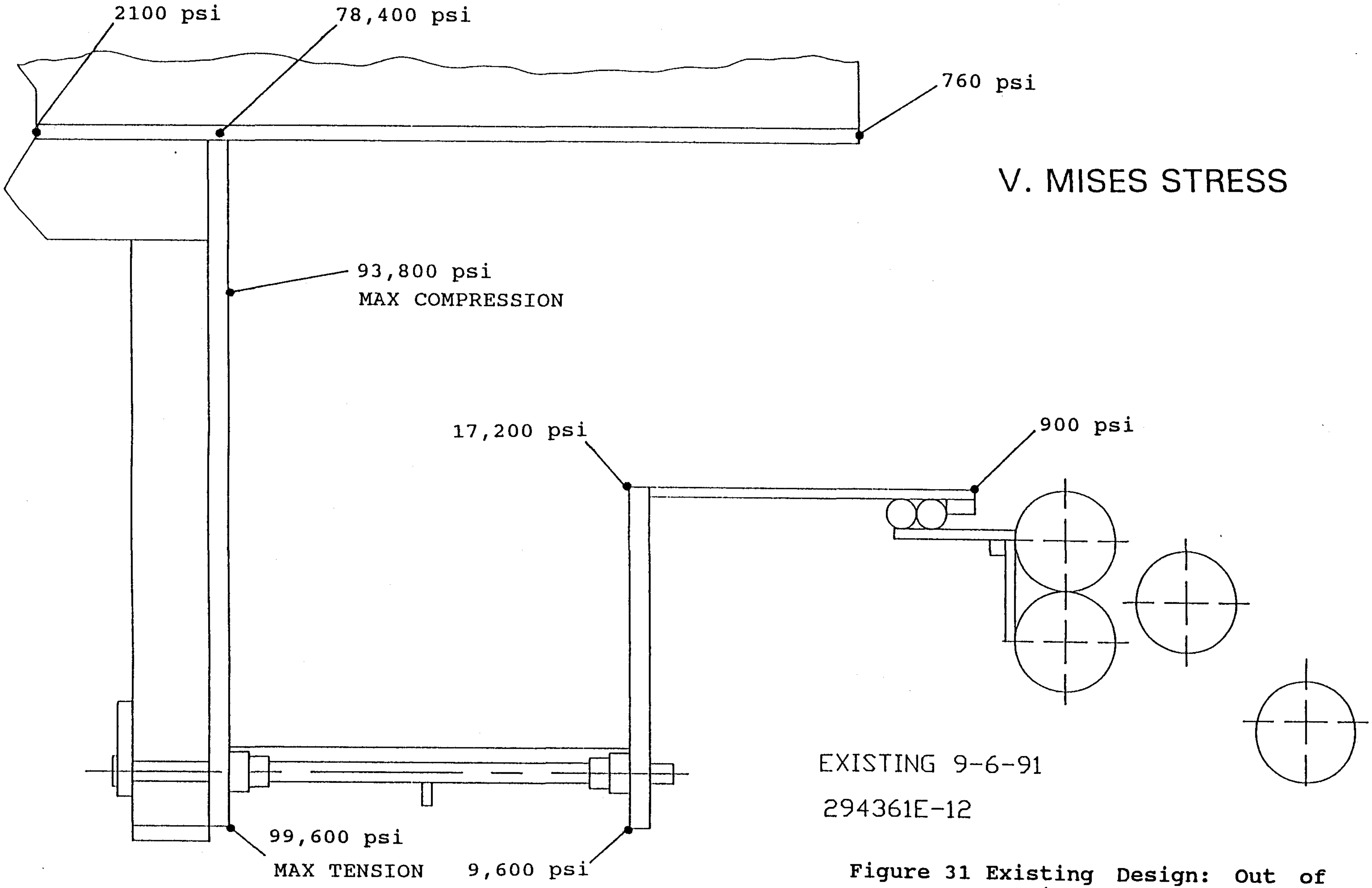


Figure 31 Existing Design: Out of Service Stress Analysis

IP7_004648

SUMMARY

EXISTING DESIGN (REF. 294361-12)
OUT OF SERVICE

BACK PLATE

- o TEMPERATURES/STRESSES AGGRAVATED BY REDUCED COOLING AIR FLOW
- o MORE SEVERE SEPARATION AND CONING/BUCKLING

INNER SLEEVE

- o MODERATE TEMPERATURES BUT STRESSES REMAIN LOW EXCEPT FOR LOCAL CONCENTRATION AT BACK PLATE ATTACHMENT
- o TEMPERATURE/STRESS RELIEF WILL OCCUR FOLLOWING SEPARATION OF BACK PLATE REDUCING LOCAL STRESS BELOW ALLOWABLE LIMITS

FRONT PLATE & THROAT SLEEVE

- o MODERATE TEMPERATURES AND STRESSES EXCEPT FOR LOCAL STRESS CONCENTRATION AT JOINT
- o PREDICTED PEAK STRESS AT JOINT APPROACHING ALLOWABLE LIMIT
- o ASSUMING SOME RECIRCULATION AND HIGHER TEMPERATURE FOR THE THROAT SLEEVE, THE STRESS WILL BE OVER THE ALLOWABLE WITH EXPECTED JOINT SEPARATION

IPPSUM2

Figure 32 Summary Existing Design: Out of Service

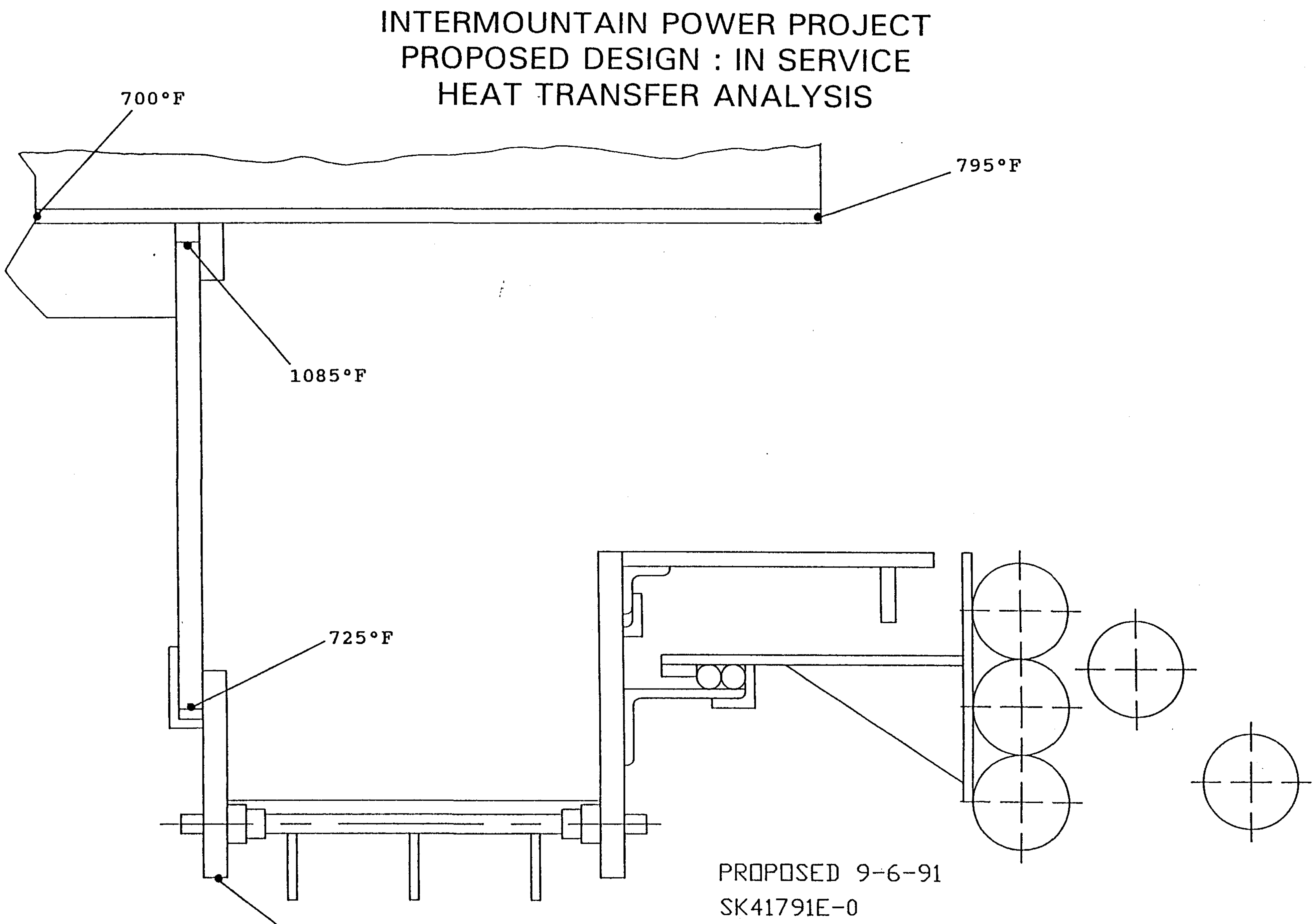


Figure 33 Proposed Design: In Service Heat Transfer Analysis

IP7_004650

INTERMOUNTAIN POWER PROJECT
PROPOSED DESIGN : IN SERVICE
STRESS ANALYSIS

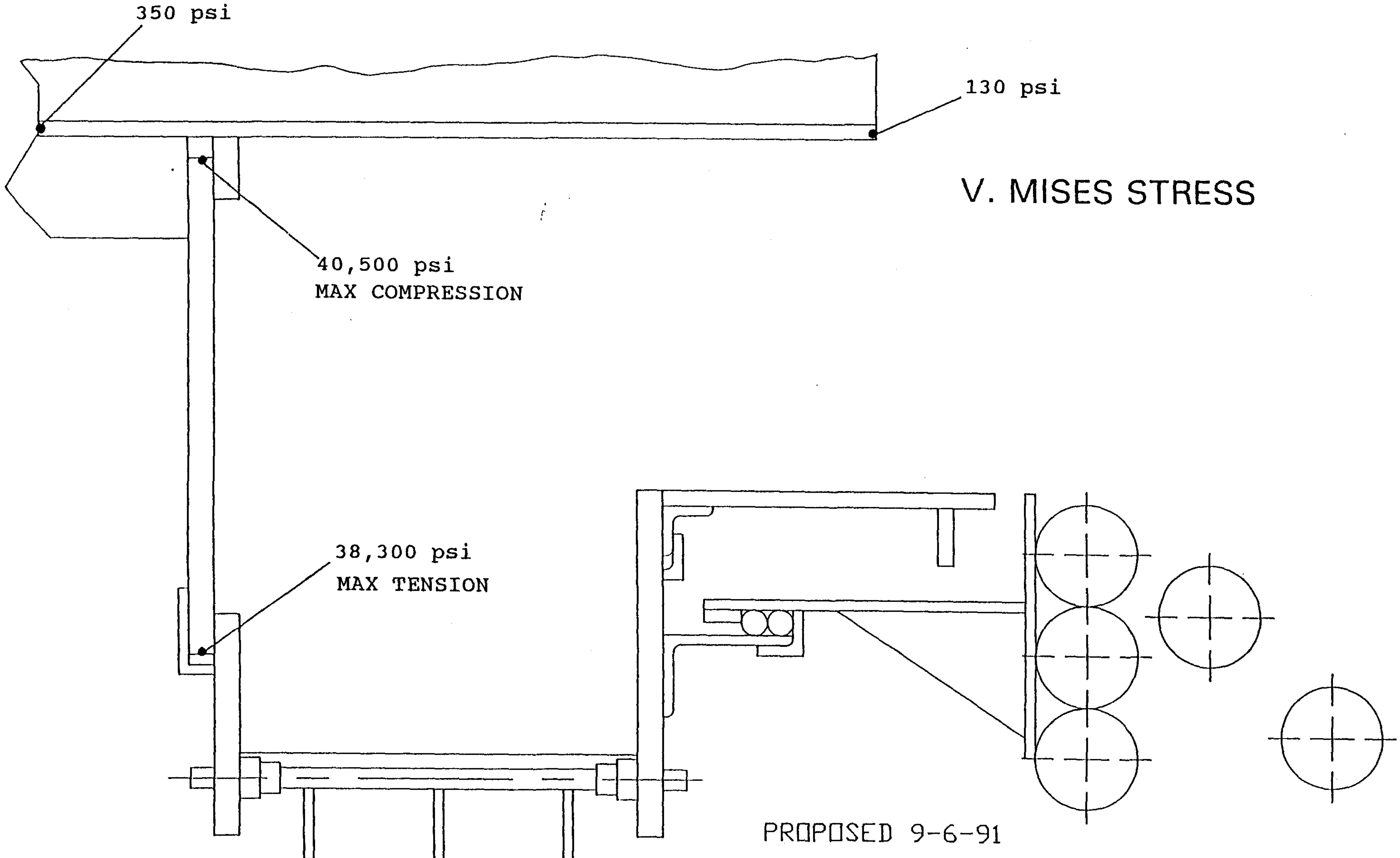


Figure 34 Proposed Design: In Service Stress Analysis

SUMMARY
PROPOSED DESIGN (REF. SK41791E-0)
IN SERVICE

BACK PLATE

- o GENERALLY SIMILAR BACK PLATE WARPING RESULTS AS IN EXISTING DESIGN
- o SLIGHTLY HIGHER TEMPERATURES DUE TO GAP AT INNER SLEEVE
- o HIGHER RADIAL TEMPERATURE GRADIENT CAUSES HIGHER TANGENTIAL STRESS GRADIENT
- o CONING/BUCKLING PREDICTED SIMILAR TO EXISTING DESIGN

INNER SLEEVE

- o LOW TEMPERATURES AND STRESSES - NO LOCAL CONCENTRATIONS

FRONT PLATE

- o ANALYSIS NOT PERFORMED - LOW TEMPERATURES/STRESSES EXPECTED THROUGHOUT

THROAT SLEEVE

- o ANALYSIS NOT PERFORMED - STRESS IN FREE CYLINDER WILL REMAIN LOW REGARDLESS OF TEMPERATURE LEVEL

IPPSUM3

Figure 35 Summary Proposed Design: In Service

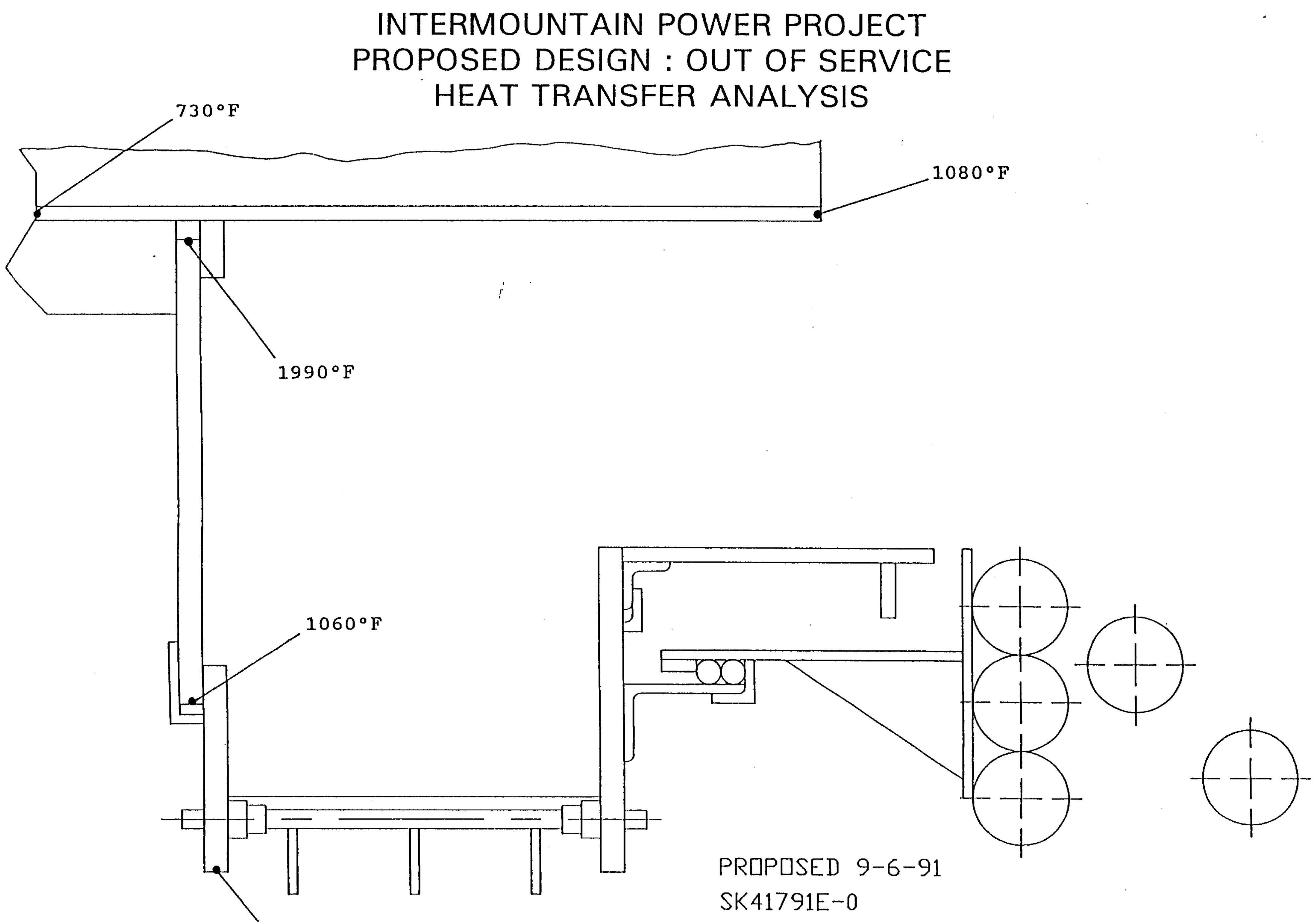


Figure 36 Proposed Design: Out of Service Heat Transfer

IP7_004653

INTERMOUNTAIN POWER PROJECT
PROPOSED DESIGN : OUT OF SERVICE
STRESS ANALYSIS

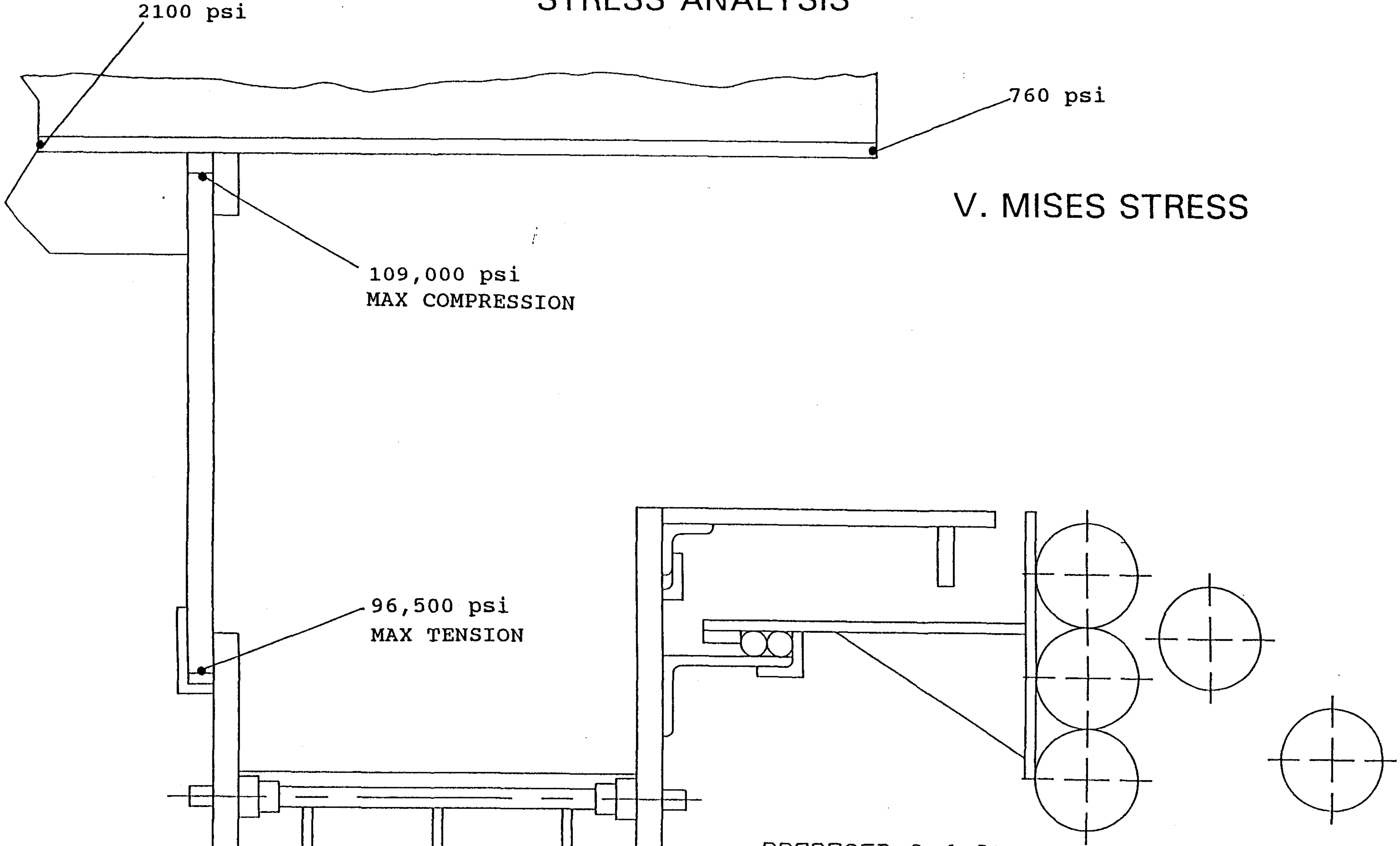


Figure 37 Proposed Design: Out of Service Stress Analysis

IP7_004654

SUMMARY
PROPOSED DESIGN (REF. SK41791E-O)
OUT OF SERVICE

BACK PLATE AND INNER SLEEVE

- o GENERALLY SIMILAR RESULTS TO "IN SERVICE", BUT HIGHER STRESSES AGGRAVATE DISTORTION.

FRONT PLATE AND THROAT SLEEVE

- o ANALYSIS NOT PERFORMED - SIMILAR LOW STRESS RESULTS AS "IN SERVICE".

IPPSUM4

Figure 38 Summary Proposed Design:
Out of Service

IP7_004655

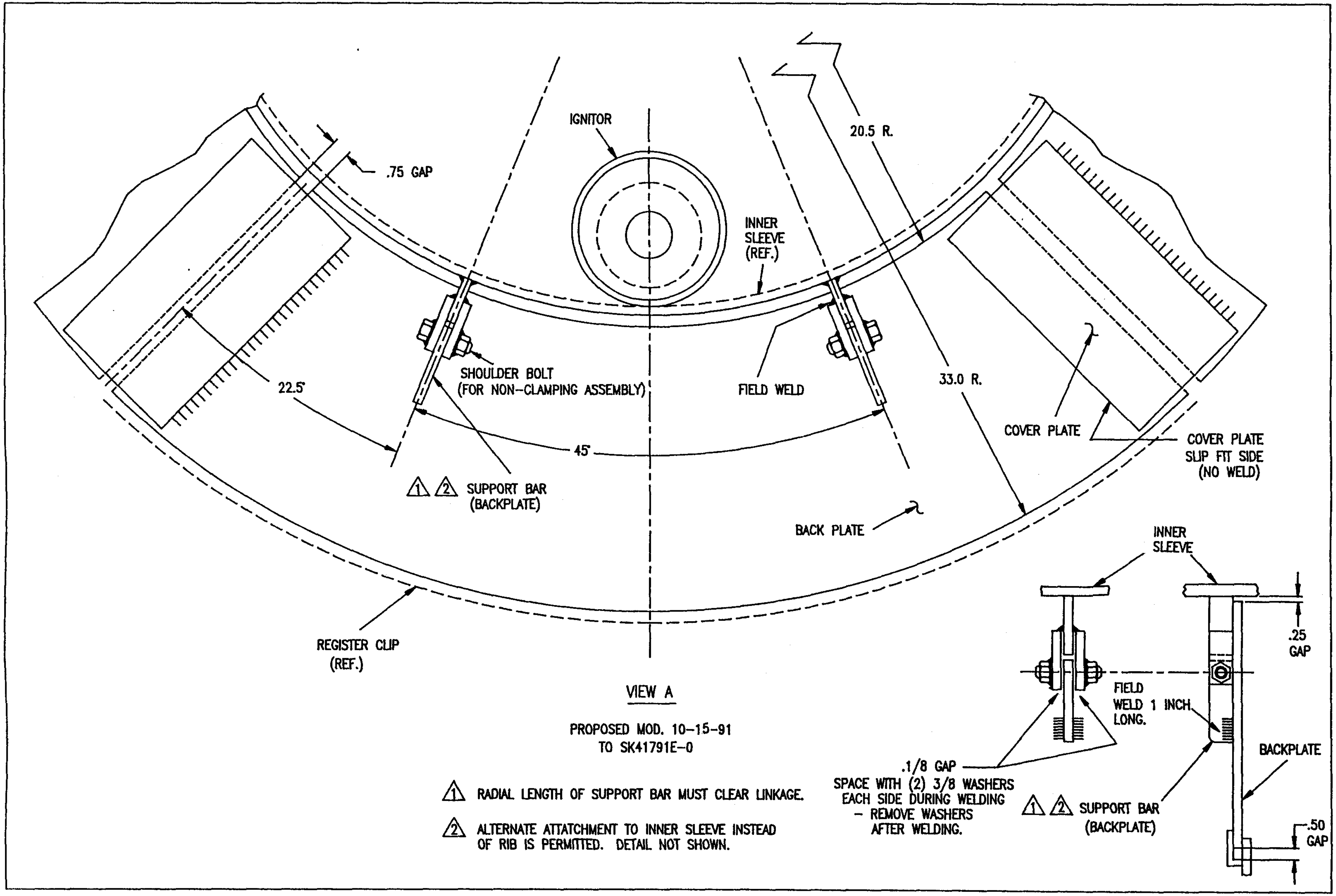


Figure 39 Segmented Back Plate

IP7_004656

RECOMMENDED BACK PLATE DESIGN
FOUR SEGMENT PANEL: **IN SERVICE**

THERMAL GROWTH

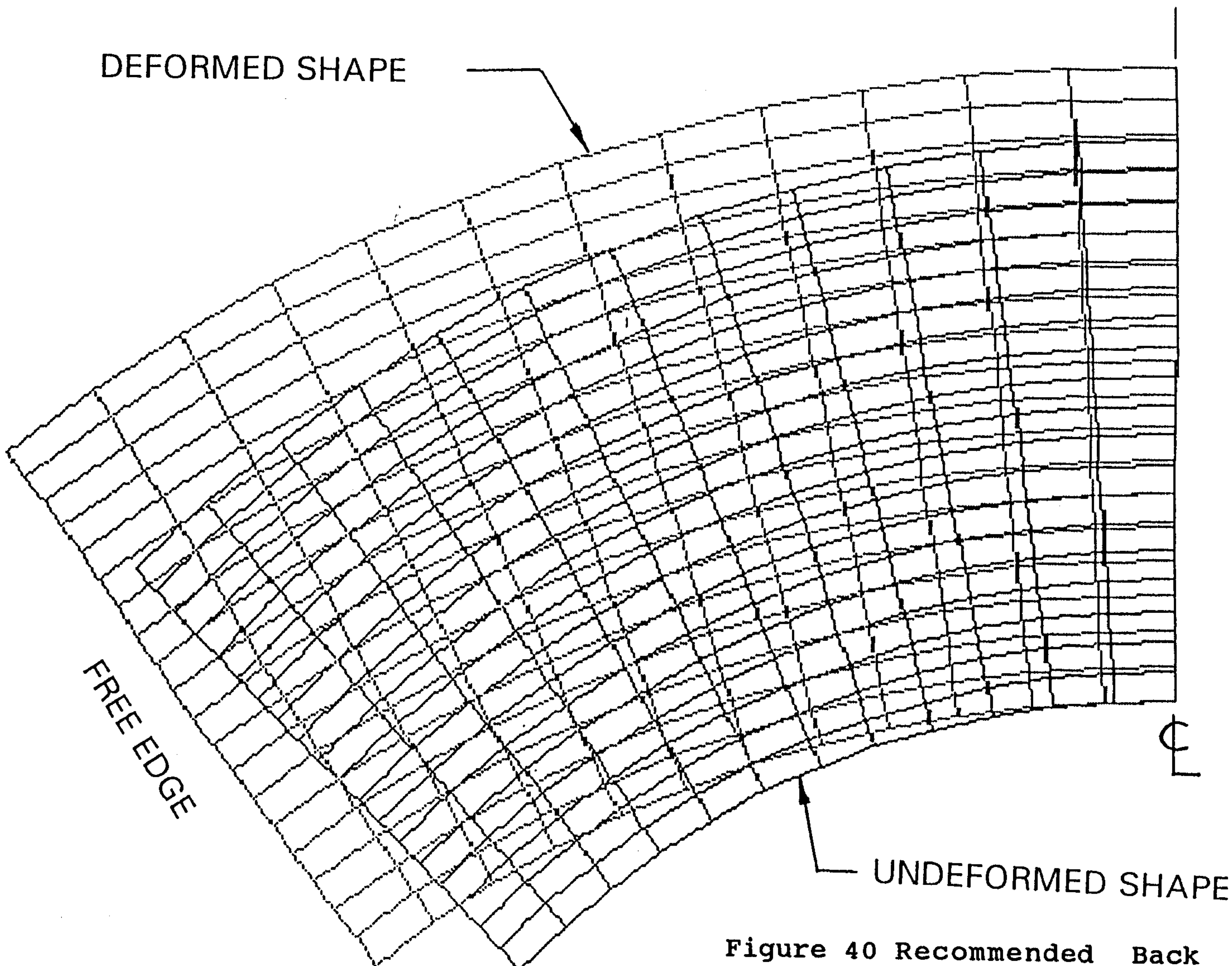
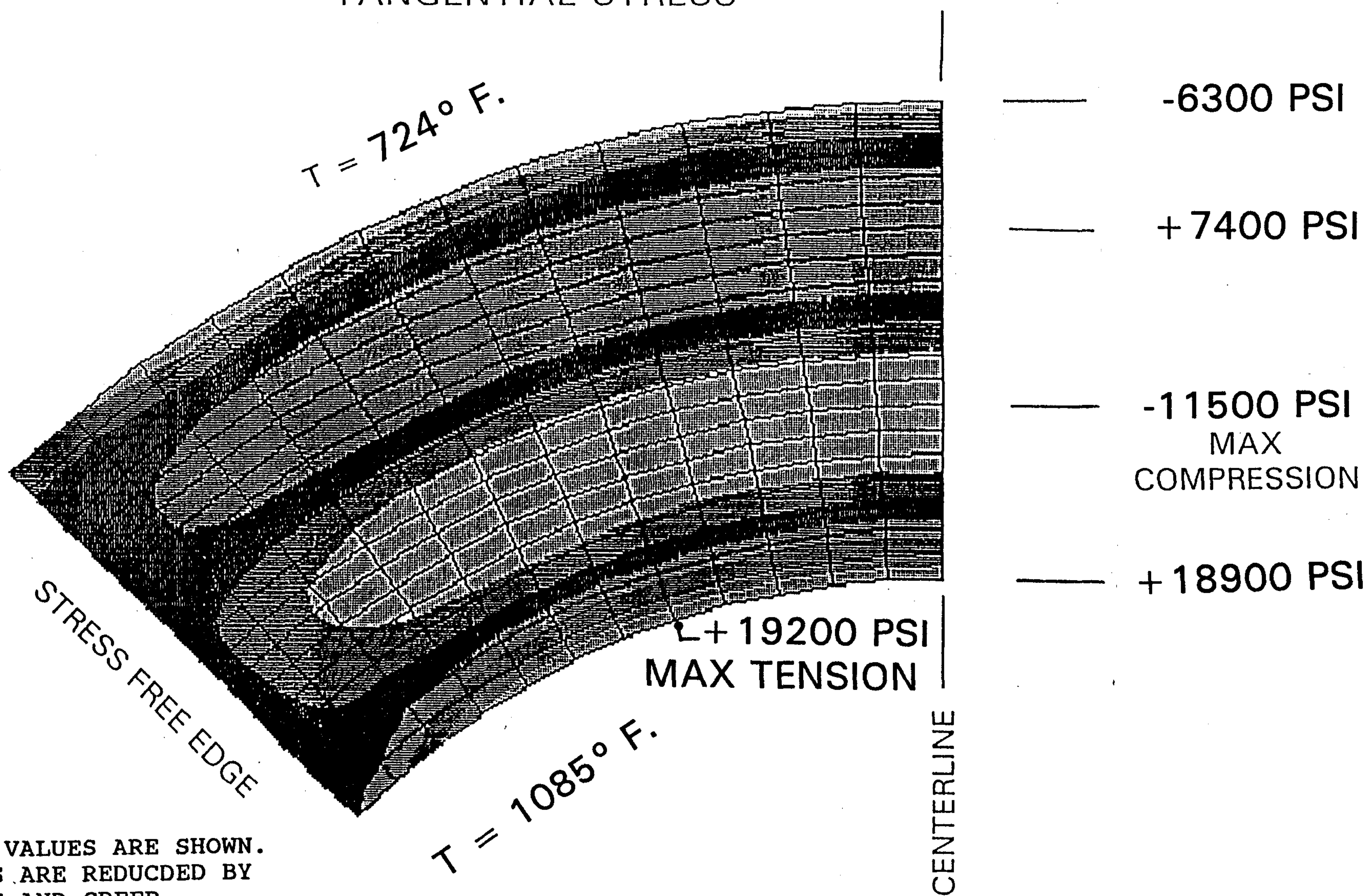


Figure 40 Recommended Back Plate Design Four Segment Panel: IN SERVICE Thermal Growth

RECOMMENDED BACK PLATE DESIGN
FOUR SEGMENT PANEL: **IN SERVICE**

TANGENTIAL STRESS



NOTE:

ELASTIC STRESS VALUES ARE SHOWN. ACTUAL STRESSES ARE REDUCDED BY PLASTIC STRAINS AND CREEP RELAXATION.

Figure 41 Recommended Back Plate Design Four Segment Panel: In Service Tangential Stress

IP7_004658

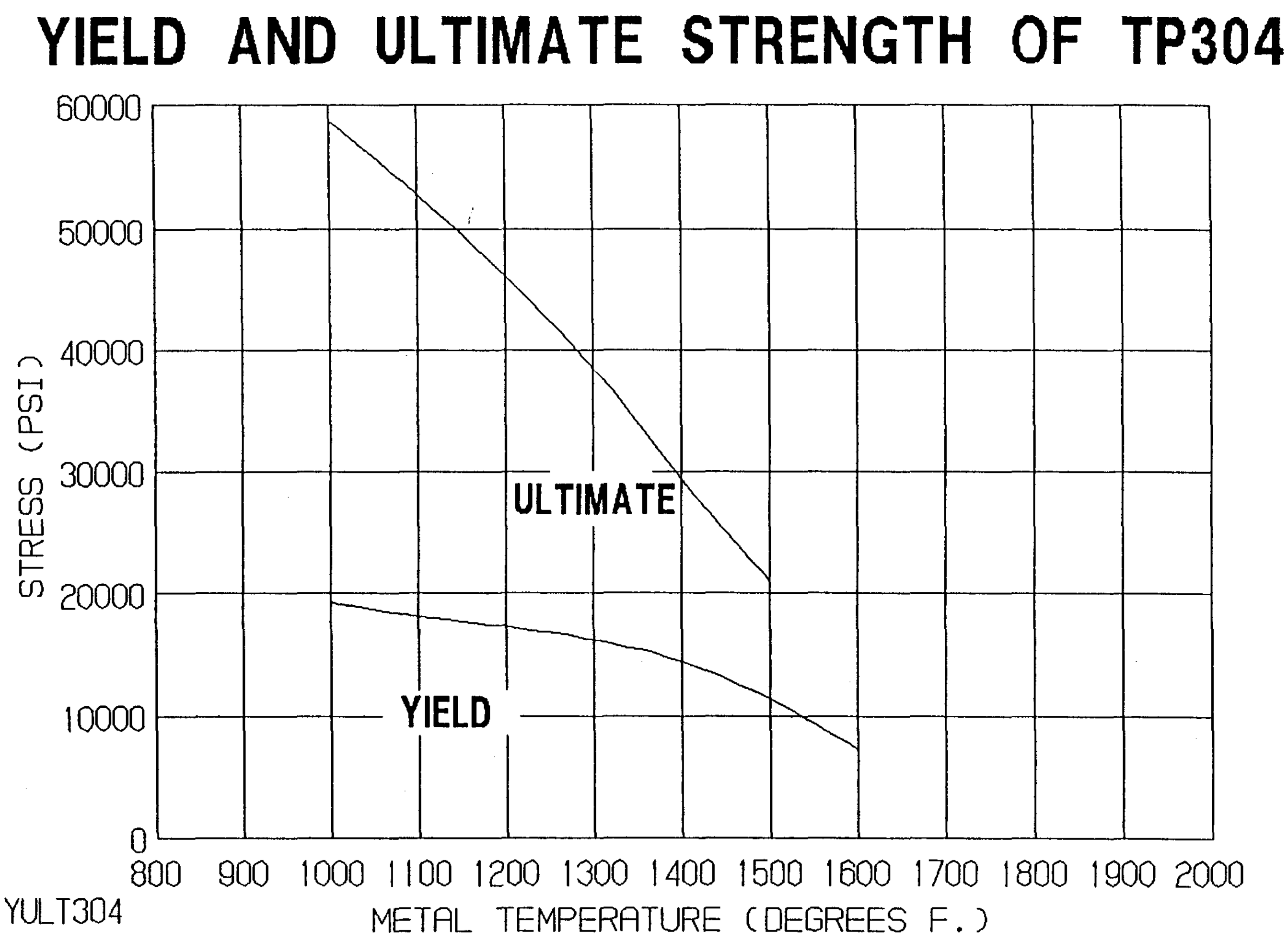
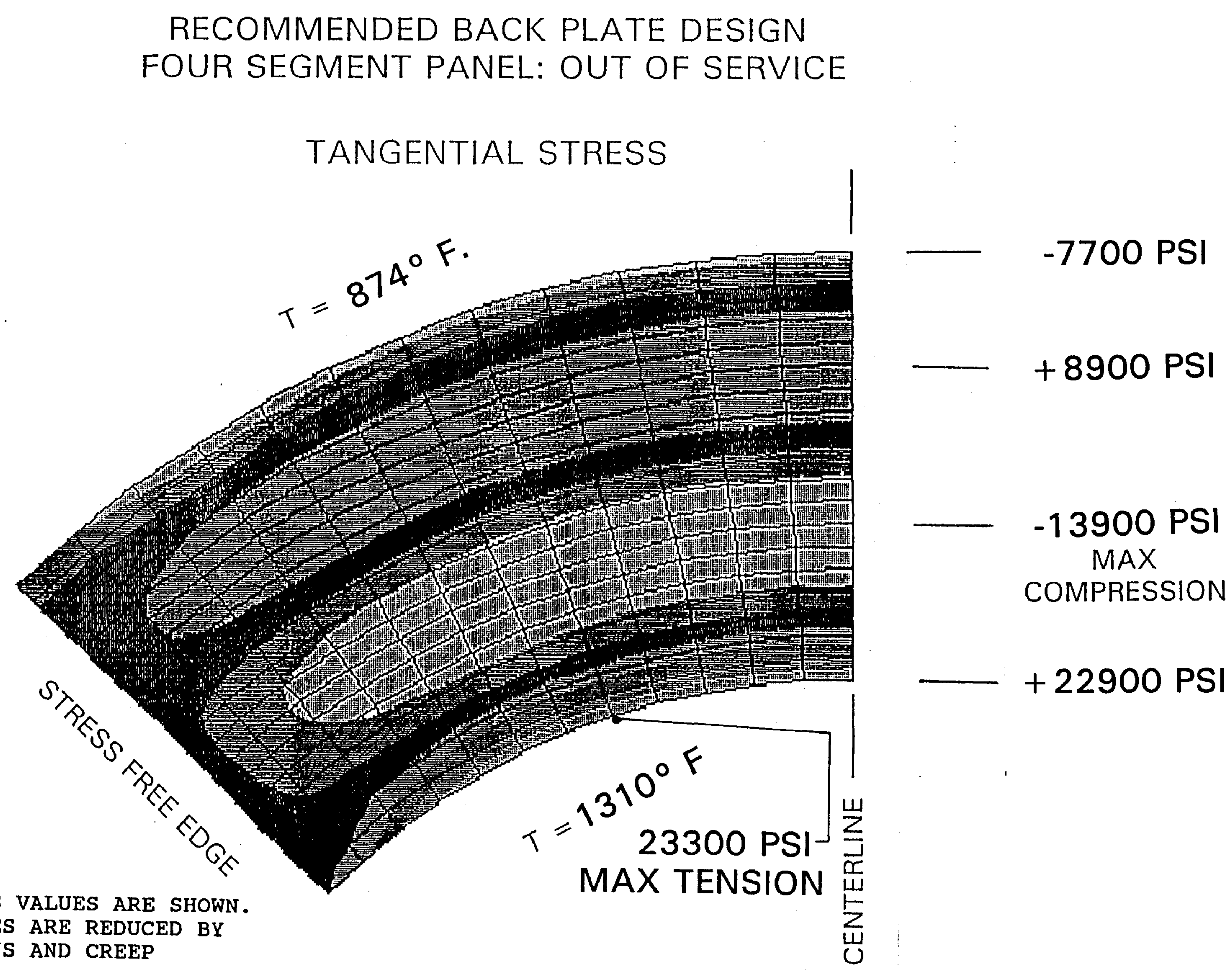


Figure 42 Yield and Ultimate
Strength of TP304



NOTE:

ELASTIC STRESS VALUES ARE SHOWN. ACTUAL STRESSES ARE REDUCED BY PLASTIC STRAINS AND CREEP RELAXATION.

Figure 43 Recommended Back Plate Design Four Segment Panel: Out of Service Tangential Stress

IP7_004660

INTERMOUNTAIN POWER PROJECT
MODIFIED BACK PLATE

DESIGN

- o FOUR 90° SEGMENTED PANELS.
- o SLIP-FIT TO THE INNER SLEEVE AND OUTER REGISTER ASSEMBLY.
- o TANGENTIAL 3/4 INCH GAP BETWEEN PANELS.
- o OVERLAP PLATES BETWEEN PANELS.
- o RADIAL CENTERING BARS.

ADVANTAGES

- o ELIMINATION OF PLATE CONING/WARPING.
- o THE GAPS ALLOW FOR THERMAL GROWTH
- o OVERLAP PLATES PREVENT AIR-FLOW THROUGH GAPS.
- o RADIAL BARS TO CENTER PLATE DURING INSTALLATION AND TO PREVENT BINDING OF THE PLATE DURING THERMAL GROWTH.

IPP.MBP

Figure 44 Modified Back Plate
Design Features

INTERMOUNTAIN POWER PROJECT
CONCLUSIONS AND RECOMMENDATIONS

BACK PLATE

- o EXISTING DESIGN SEPARATION AND BUCKLING CAUSED BY HIGH TANGENTIAL STRESS GRADIENT.
- o PROPOSED DESIGN DOES NOT RELIEVE STRESS GRADIENT, SO SIMILAR SEPARATION AND BUCKLING ARE EXPECTED.
- o IT IS RECOMMENDED THAT PROPOSED SLIP FIT PLATE BE DIVIDED INTO SEPARATE PANELS TO ELIMINATE TANGENTIAL STRESS GRADIENT.
- o SAME MATERIAL AND THICKNESS AS EXISTING DESIGN IS THEREFORE ADEQUATE.

INNER SLEEVE AND THROAT SLEEVE

- o ACT AS FREE CYLINDERS WHEN SEPARATED FROM PLATES RESULTING IN LOW STRESSES REGARDLESS OF TEMPERATURE.
- o SAME MATERIAL AND THICKNESS AS EXISTING DESIGNS ARE THEREFORE ADEQUATE.

FRONT PLATE

- o EXISTING DESIGN STRESS CONCENTRATION AT JOINT WITH THROAT SLEEVE ELIMINATED BY SLIP FIT PROPOSED DESIGN.
- o SAME MATERIAL AND THICKNESS AS EXISTING DESIGN IS THEREFORE ADEQUATE.

IPPCON

Figure 45 Structural Analysis Conclusions and Recommendations

INTERMOUNTAIN POWER PROJECT
RECOMMENDED MATERIALS

(BASED ON SLIP FIT/SEGMENTED PANEL BACK PLATE AND SLIP FIT FRONT PLATE)

COMPONENT	MATERIAL
REGISTER FRONT PLATE	1/2" A36 PLATE *
REGISTER BACK PLATE	1/2" TP304H PLATE *
INNER AIR SLEEVE	1/4" TP309H PLATE *
THROAT SLEEVE	1/4" TP304H PLATE *
SLIP SEAL CASING	3/16" TP304H PLATE *
COAL PIPE TIP	1/2" TP309H PLATE *

(* - DENOTES MATERIAL AS IS CURRENTLY INSTALLED)

IPP.RM

IP7_004663

Figure 46 Recommended Materials

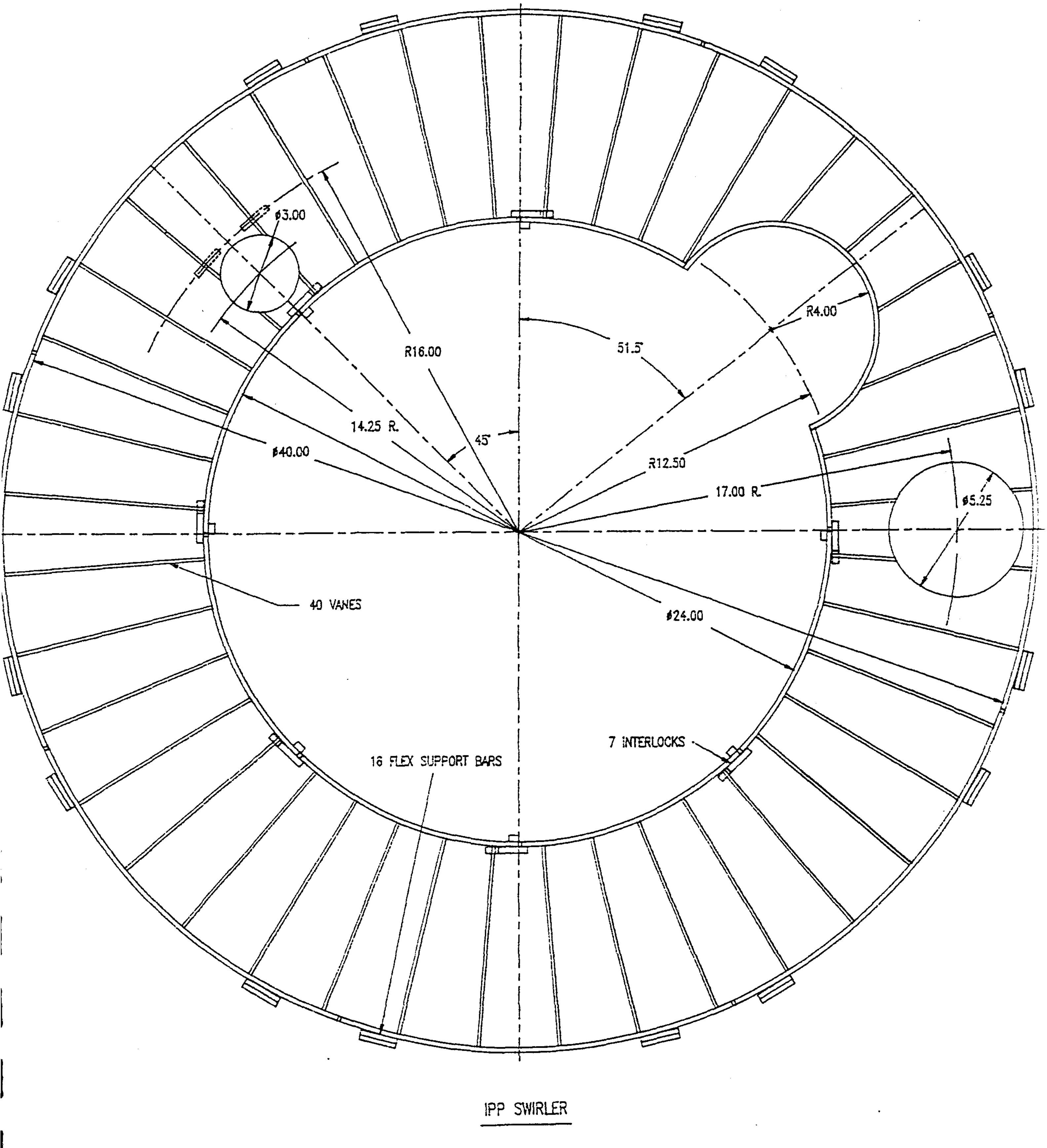


Figure 47 Intermountain Power Project Swirler

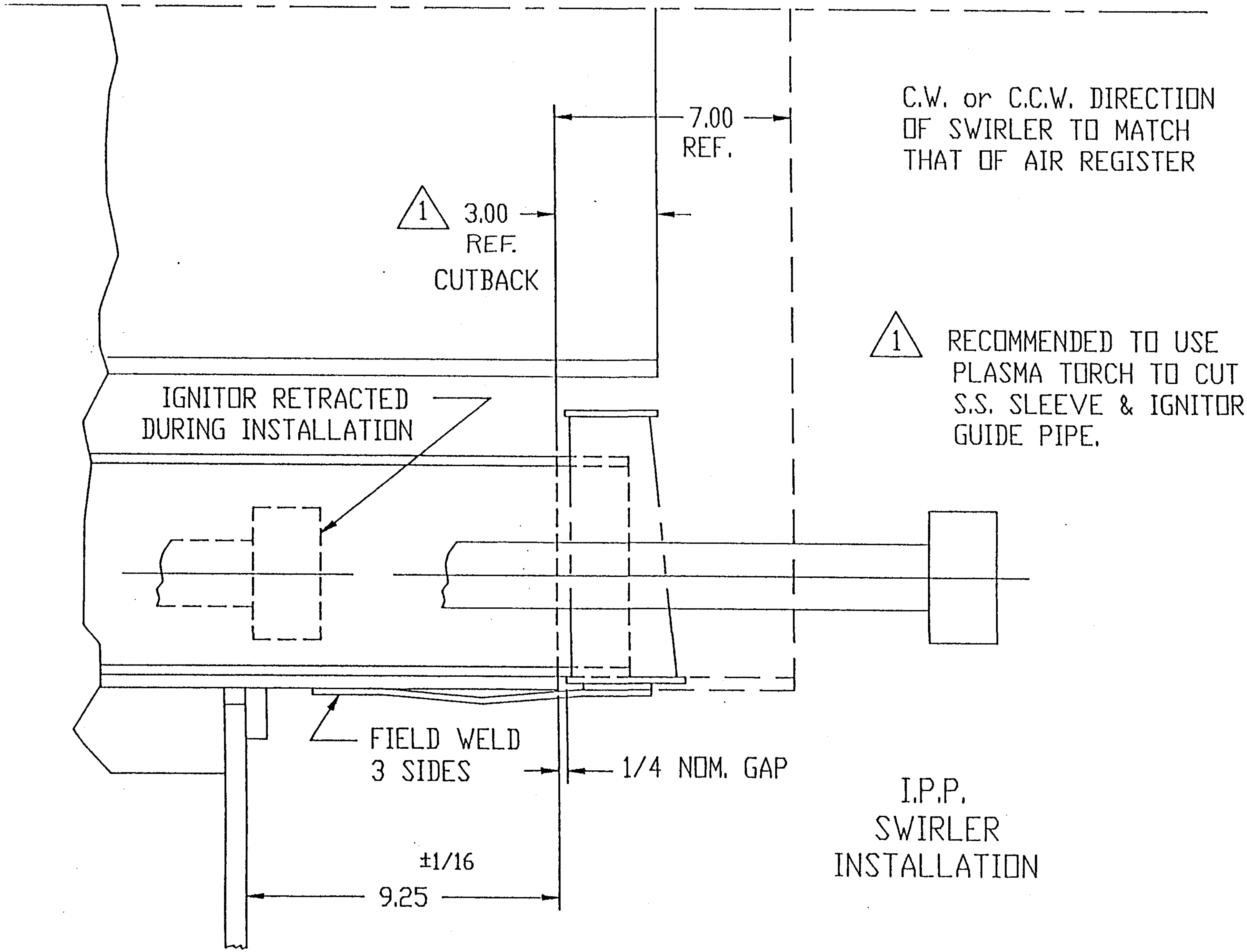


Figure 48 Swirler Installation

IP7_004665

INTERMOUNTAIN POWER PROJECT
SWIRLER

DESIGN

- 40 VANES WELDED TO INNER AND OUTER SHROUD
- ATTACHES TO COAL NOZZLE BY 16 FLEX BAR SUPPORTS
- INNER SHROUD INTERLOCK PINNED TO SEGMENTS

ADVANTAGES

- SEGMENTED DESIGN ALLOWS FOR THERMAL GROWTH BETWEEN THE OUTER SHROUD AND THE COAL NOZZLE
- INTERLOCK PIN DESIGN PERMITS RADIAL AND TANGENTIAL THERMAL GROWTH WHILE CONSTRAINING AXIAL SEGMENT MOVEMENT

IPP.SWL

Figure 49 Swirler Design Features

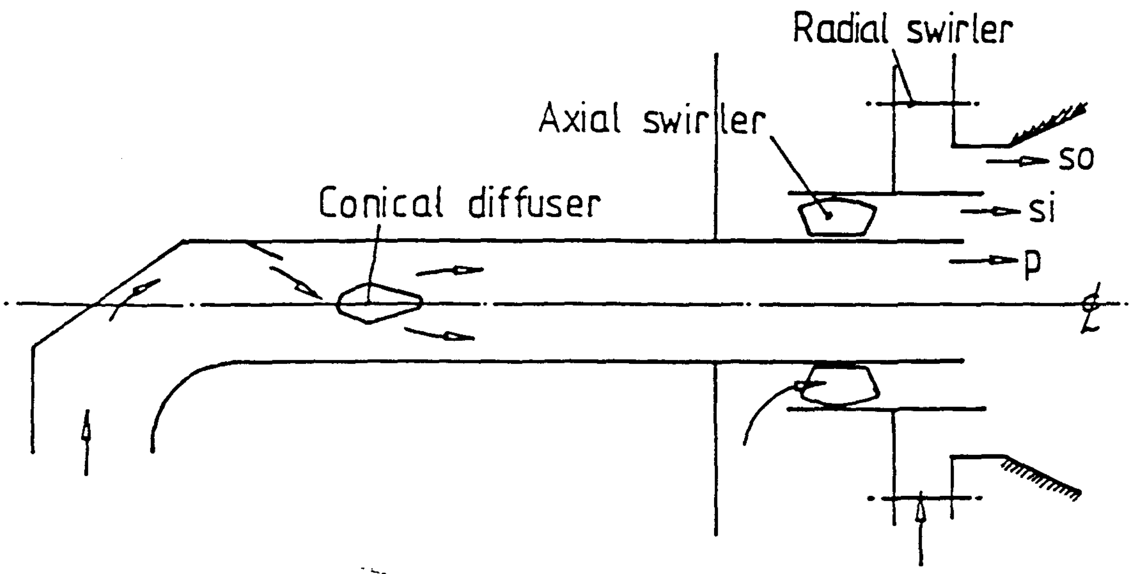


Figure 50 A dual-register burner. (After La Rue (1982).)

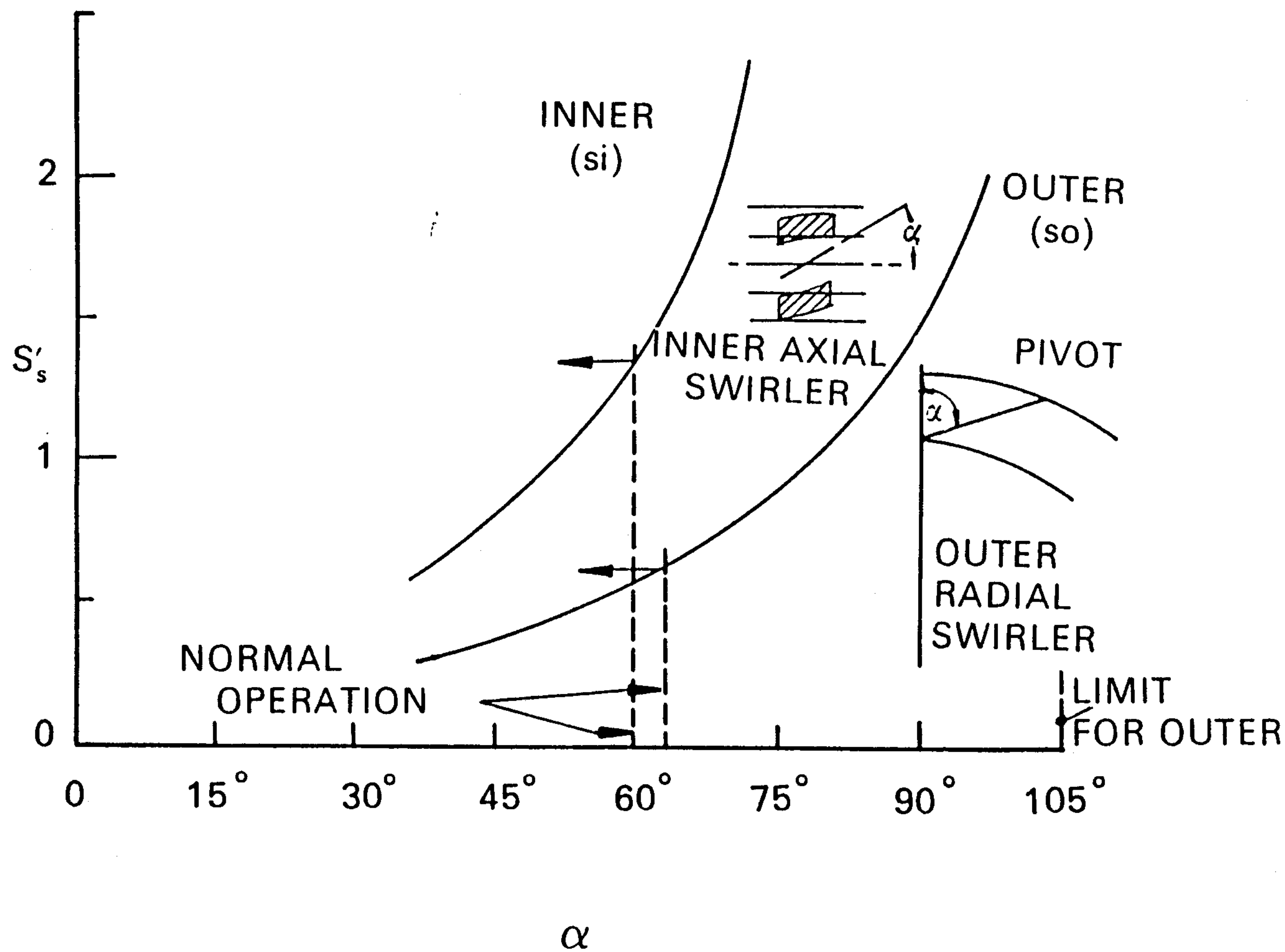


Figure 51 Swirl numbers estimated for the flows from the two registers of Figure **50**

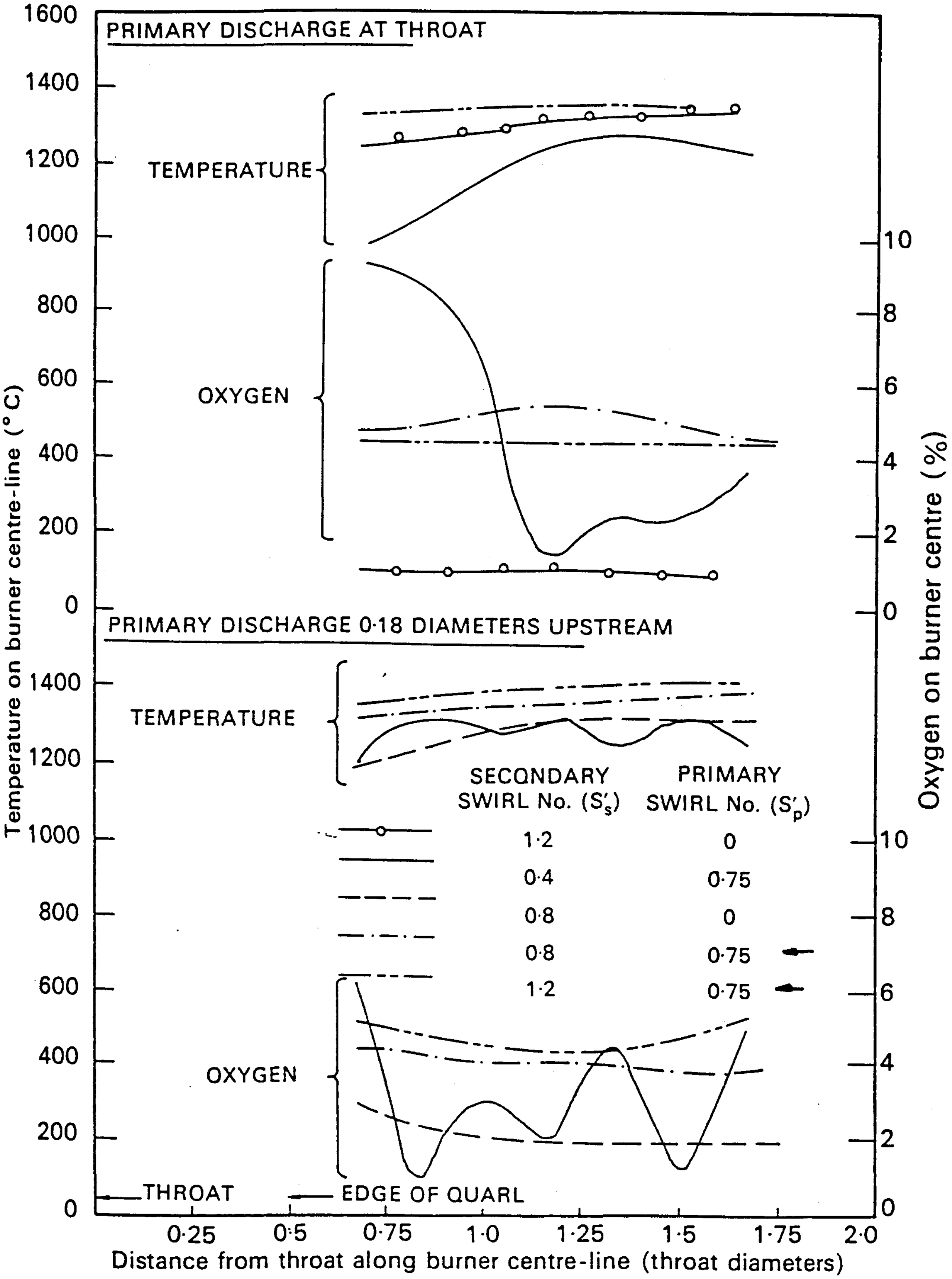


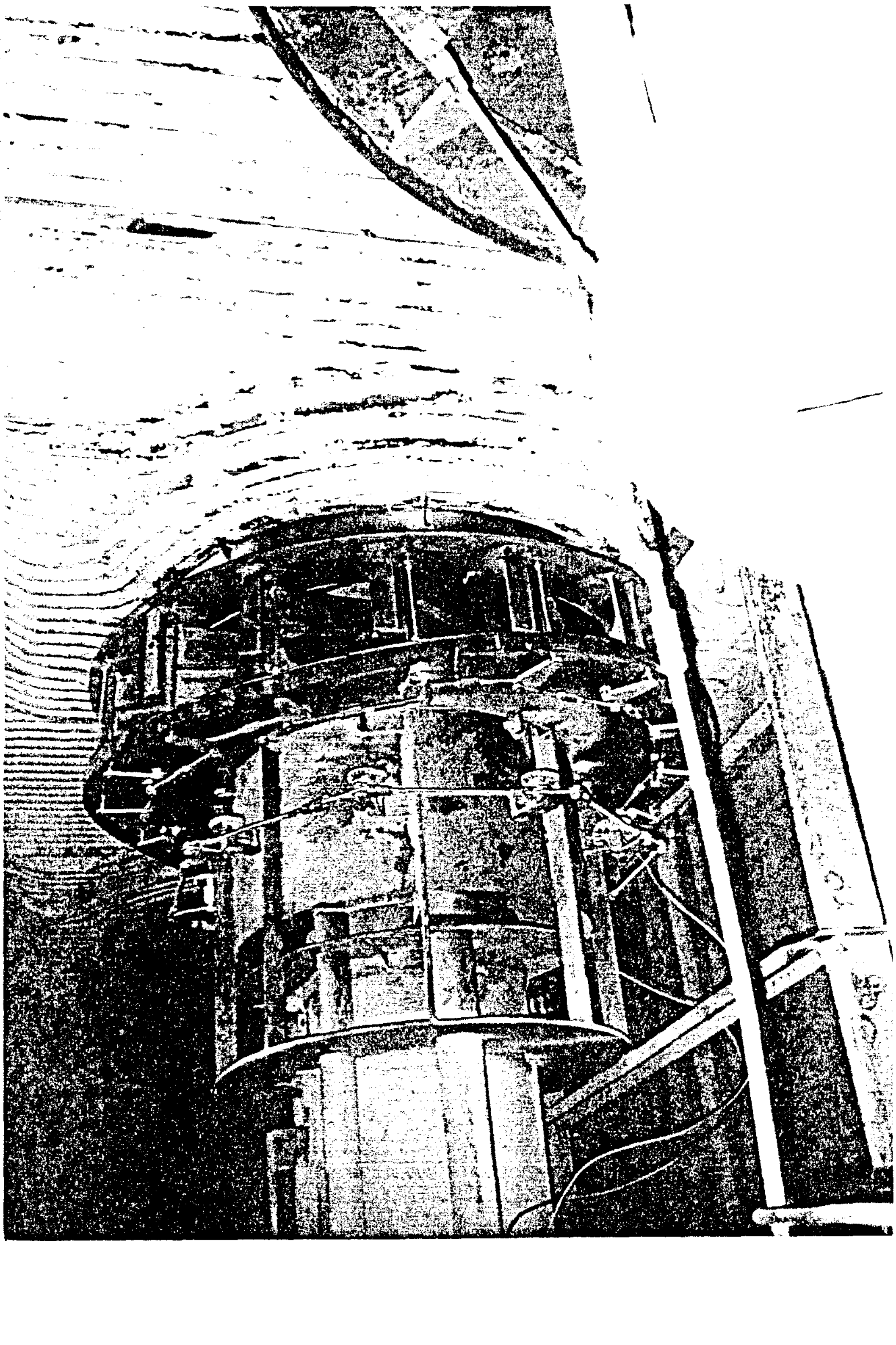
Figure 52 The effect of swirl on axial temperature and oxygen profiles. (After Jeremiejczyk (1978).)

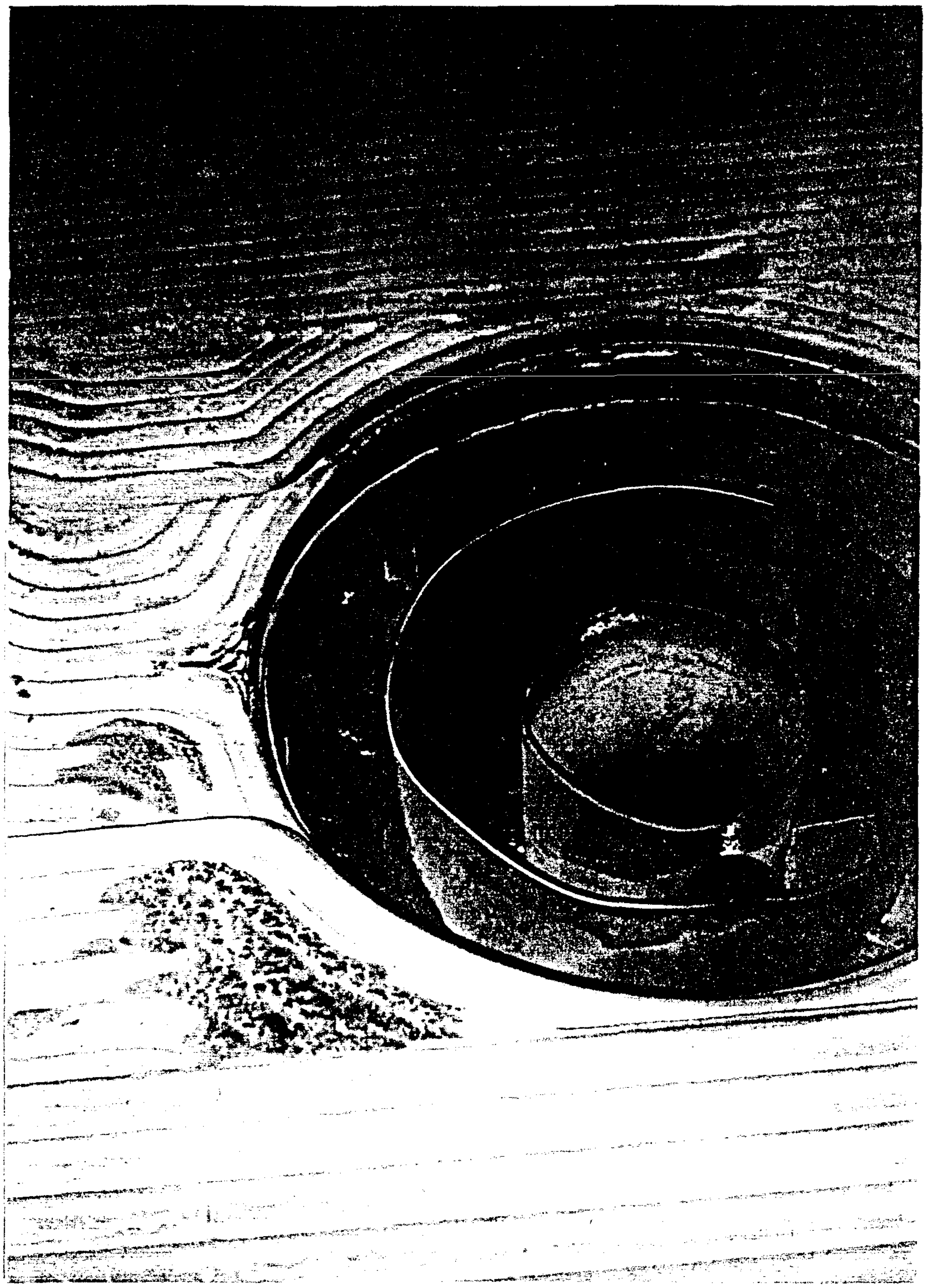
IP7_004669

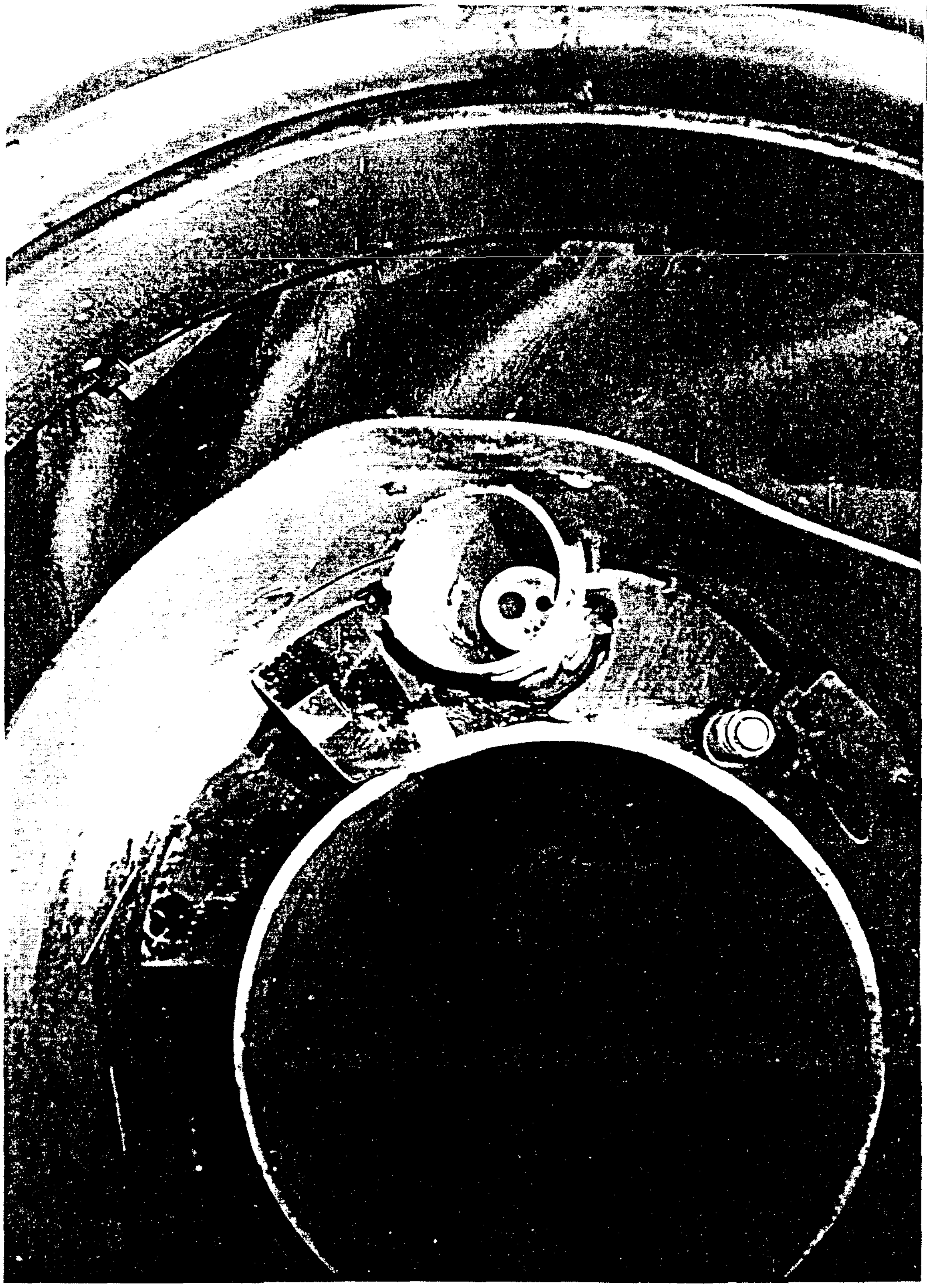
APPENDIX I

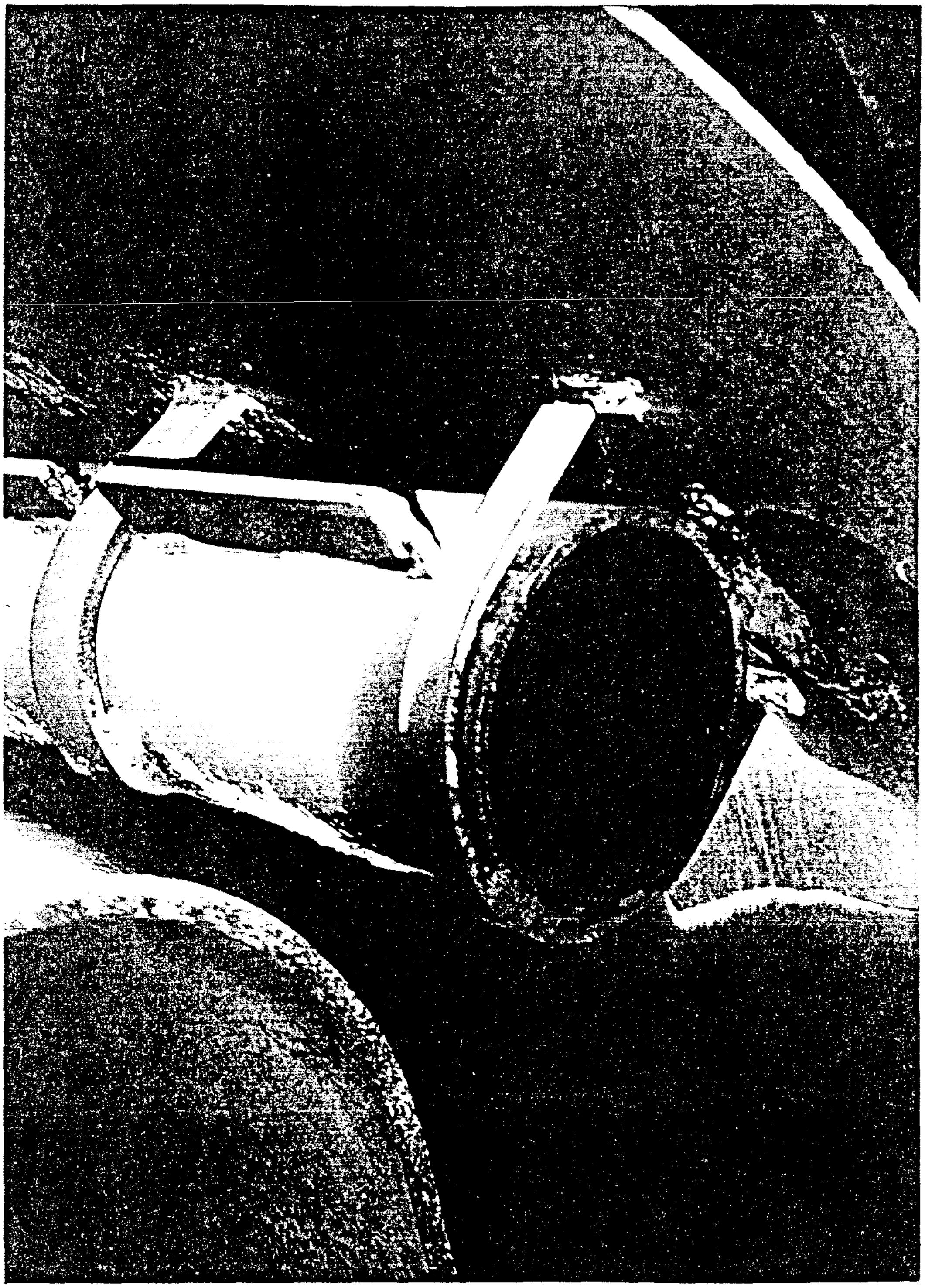
INTERMOUNTAIN POWER PROJECT

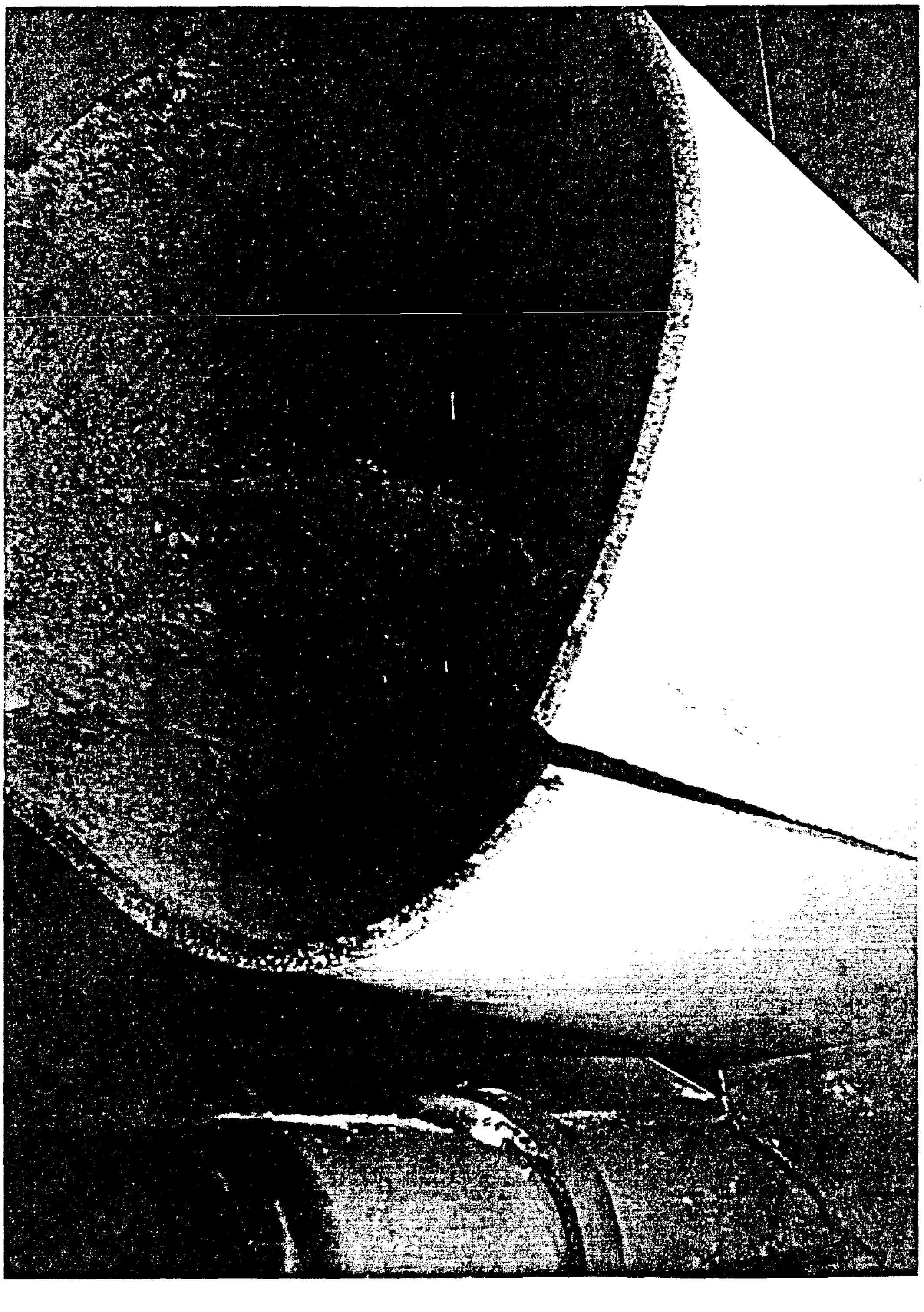
BURNER PHOTOGRAPHS



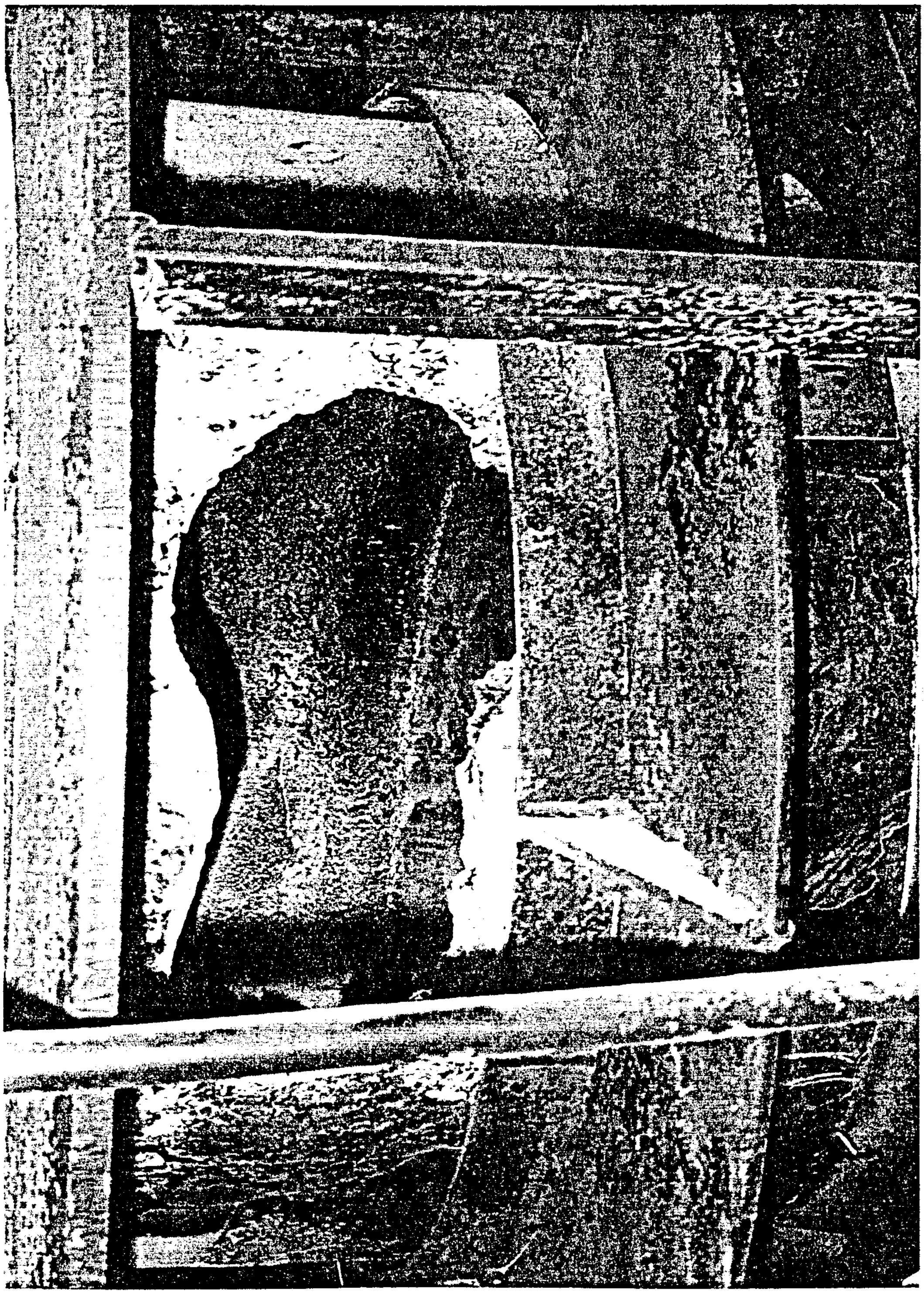


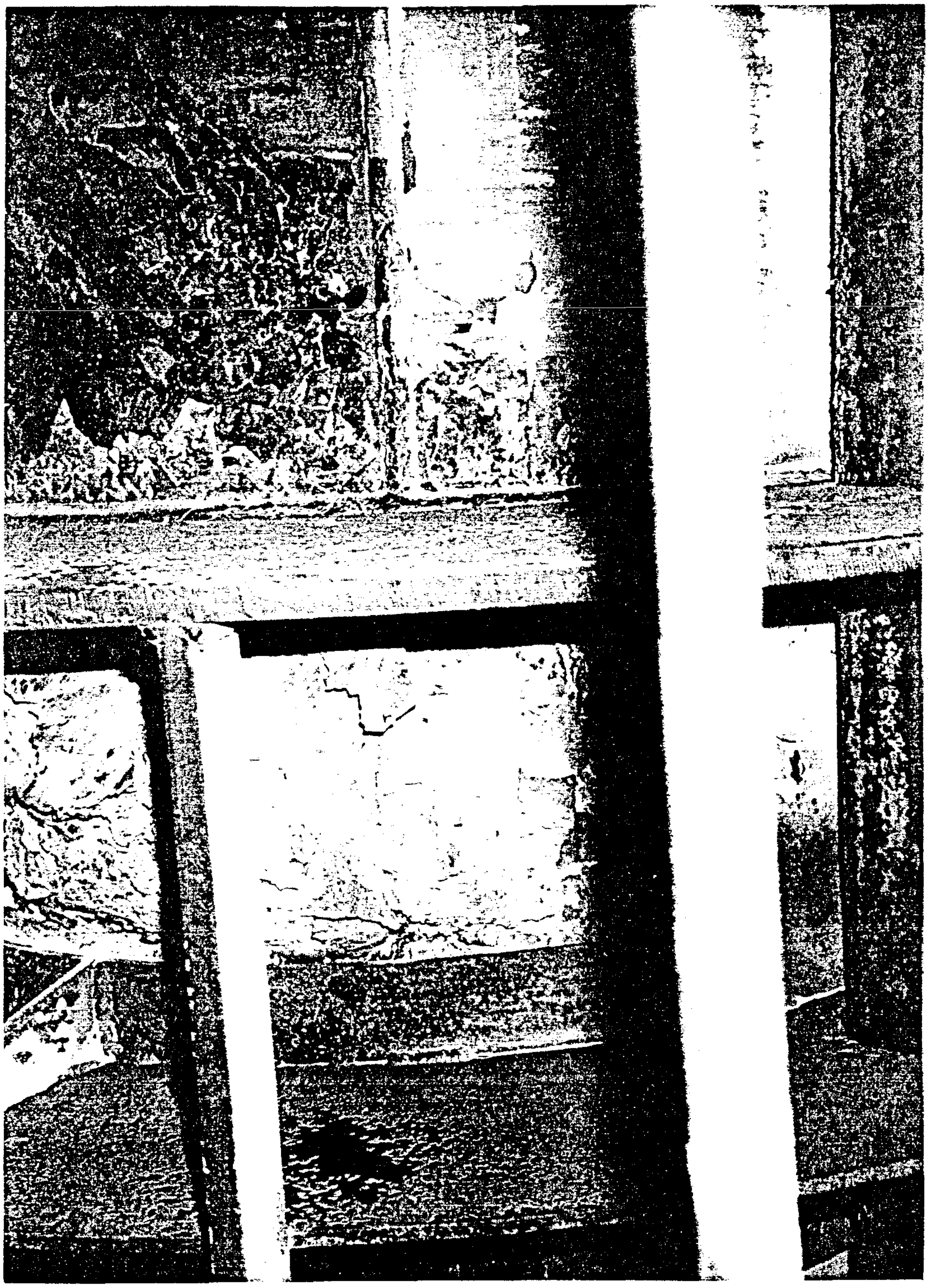


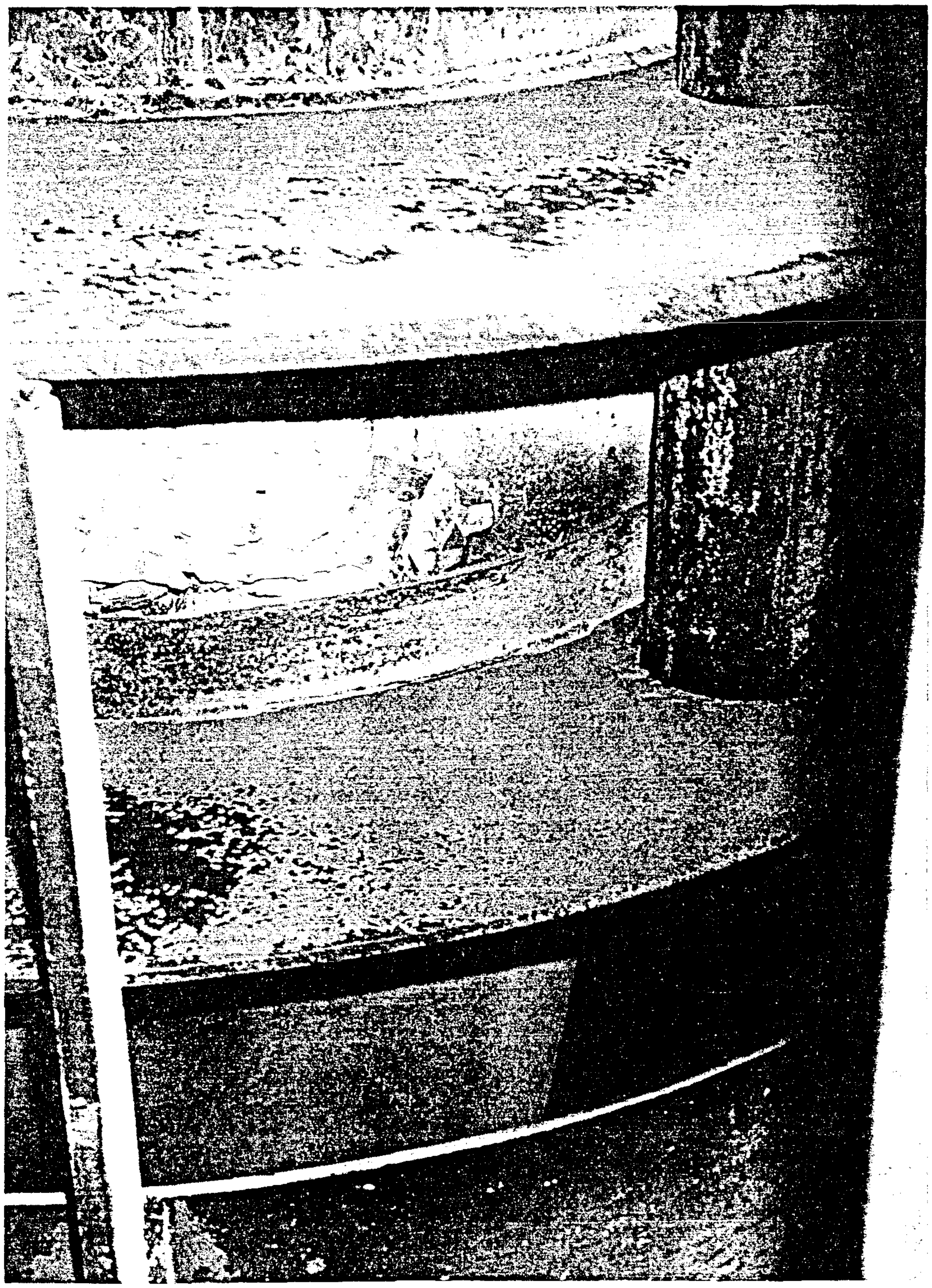


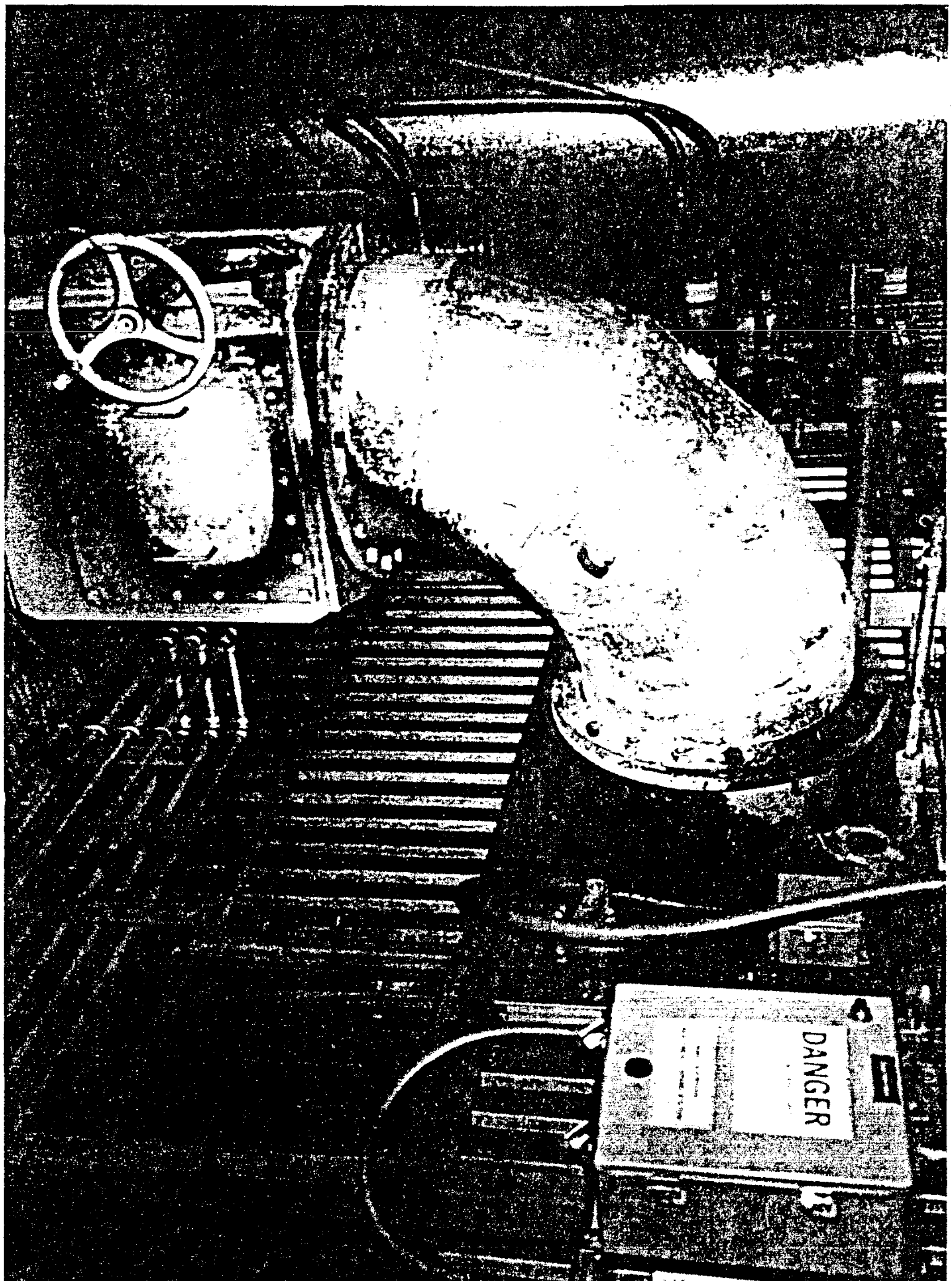


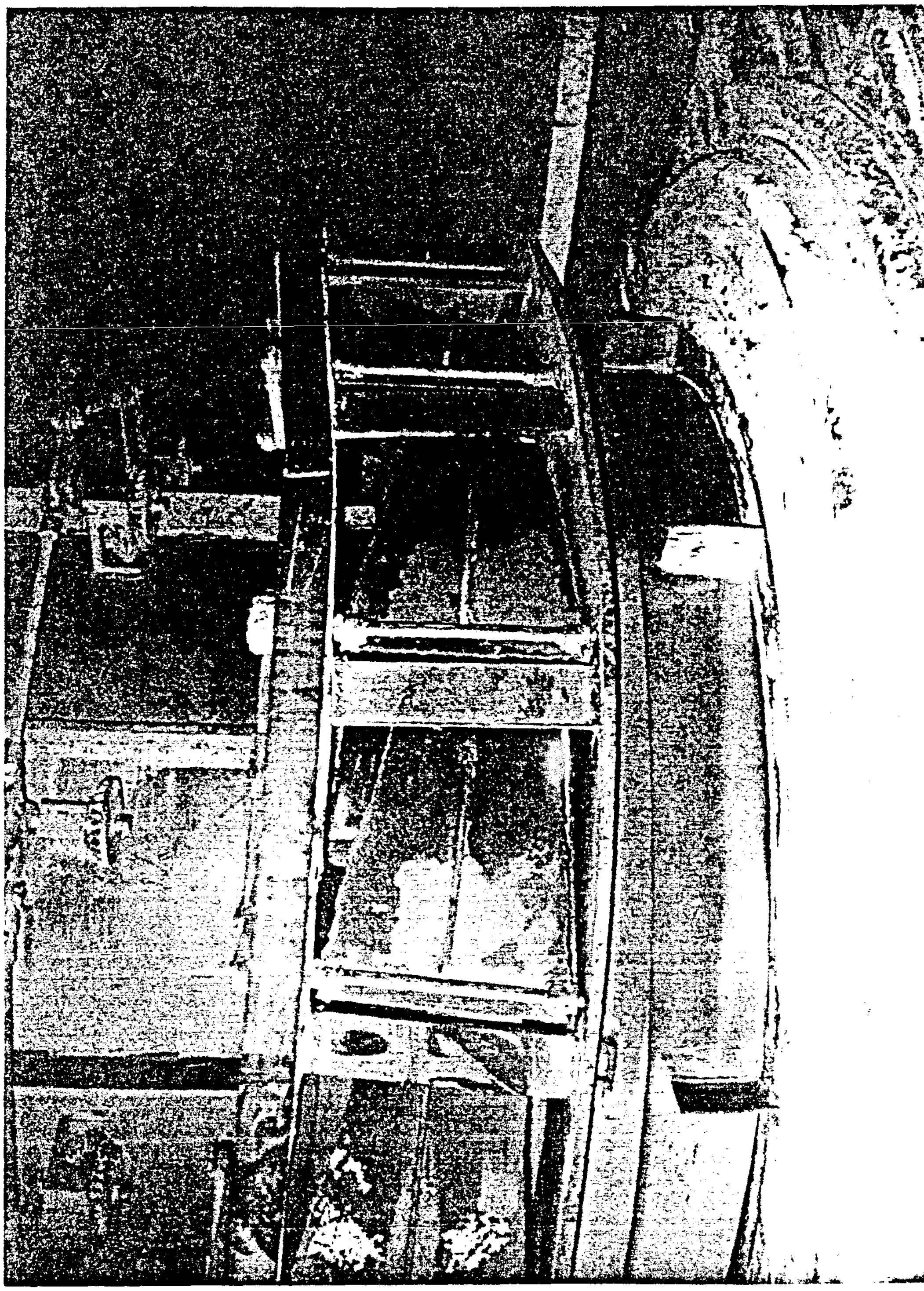
IP7_004678

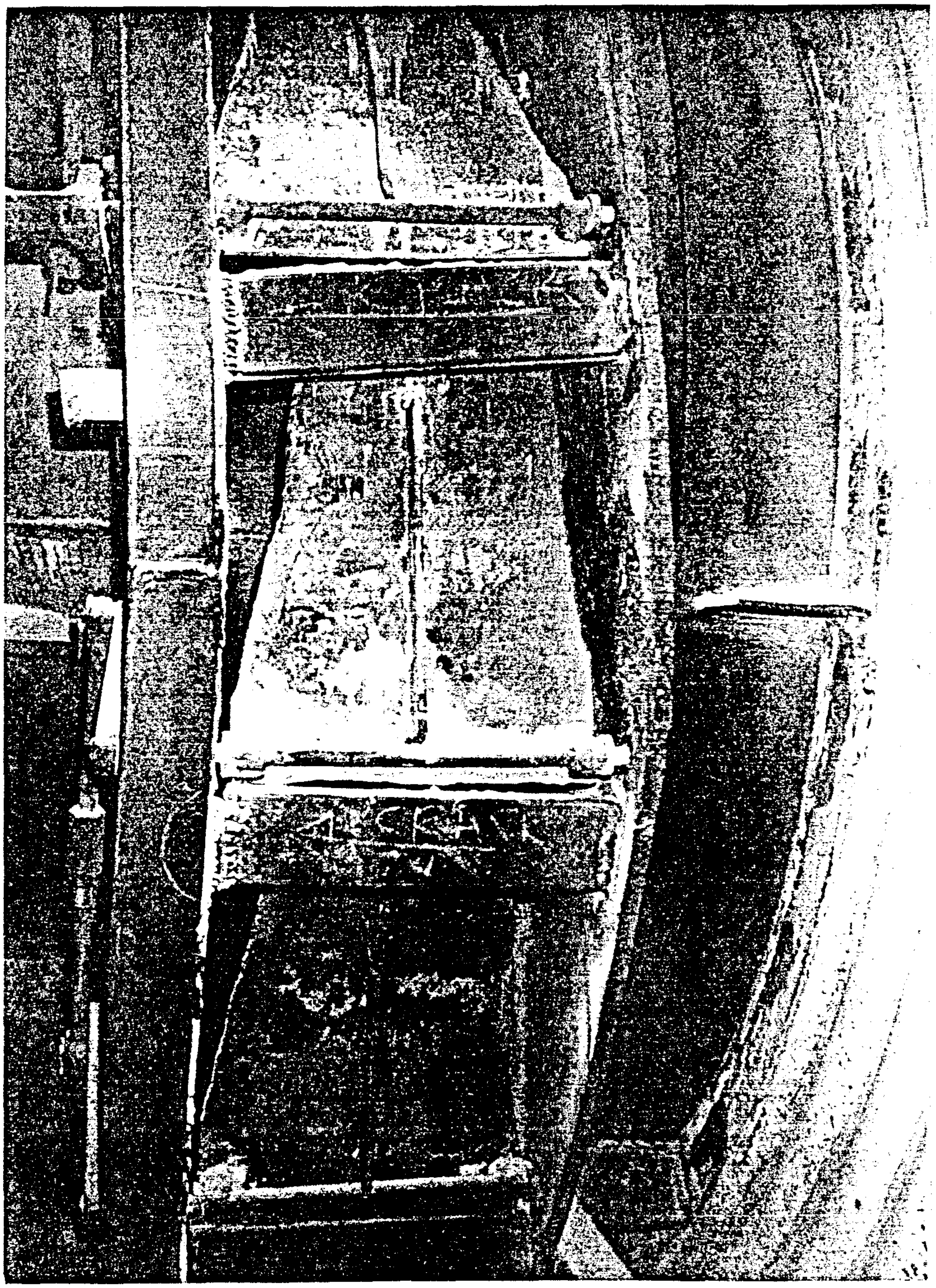







DANGER





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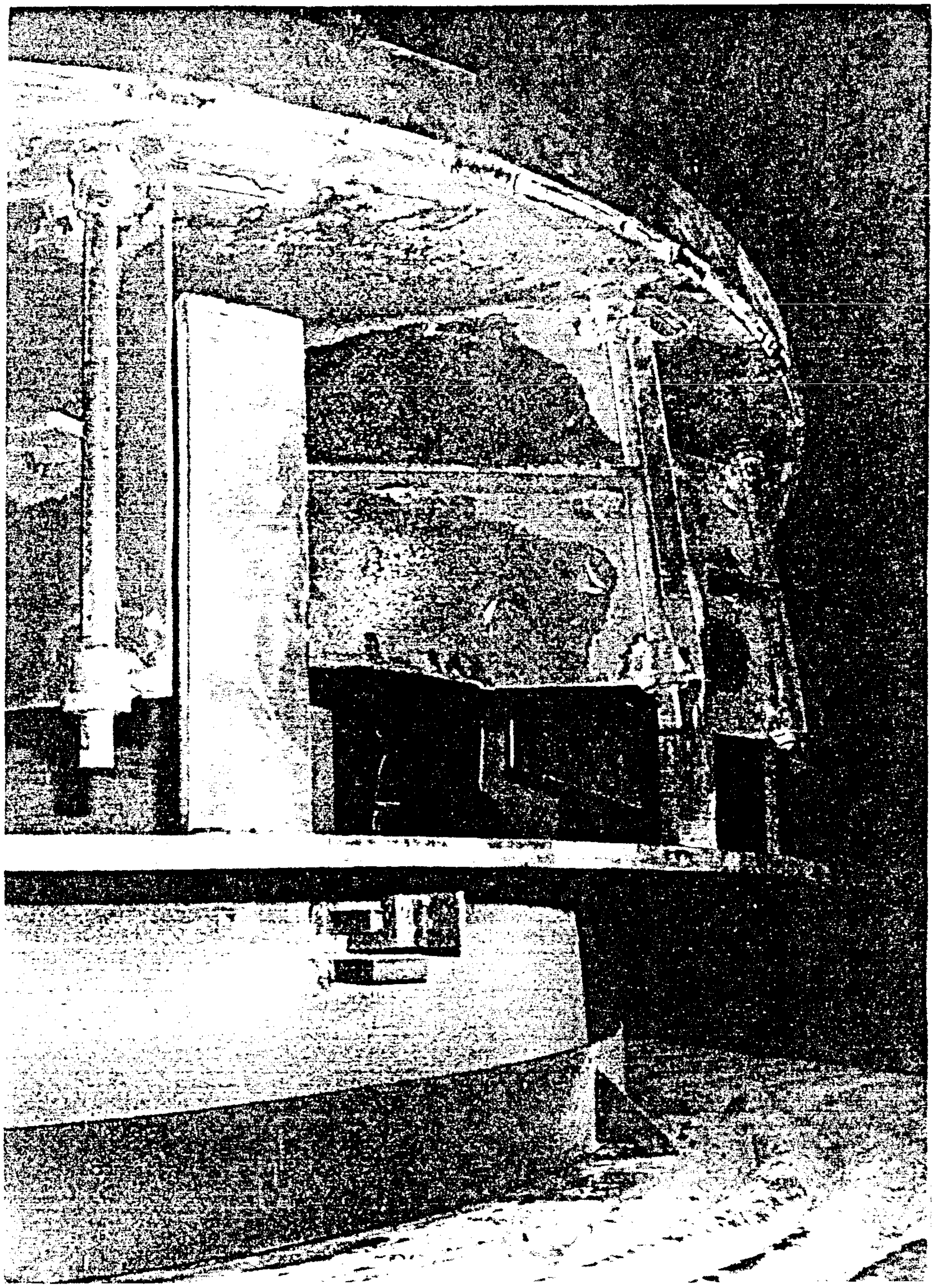

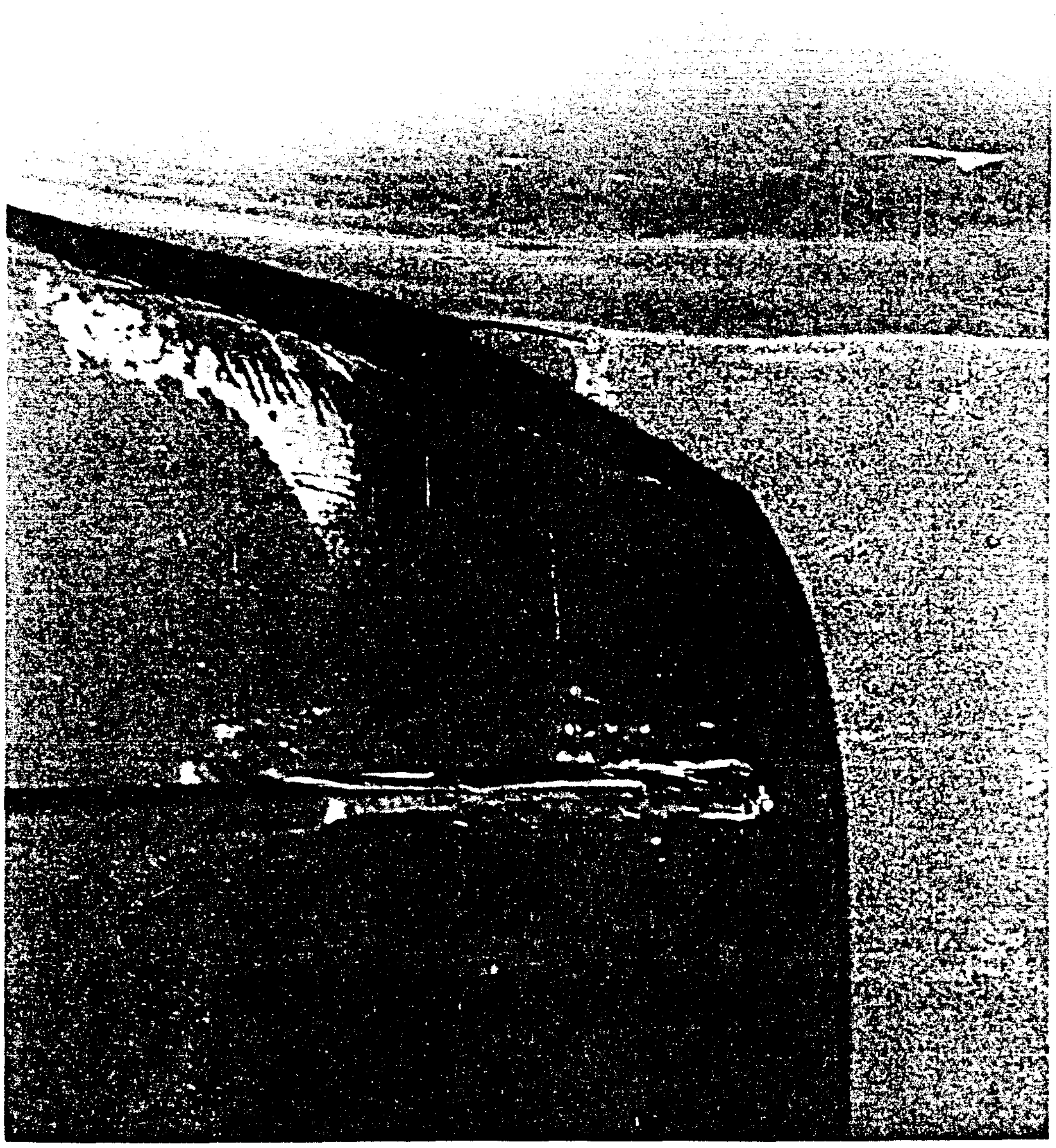

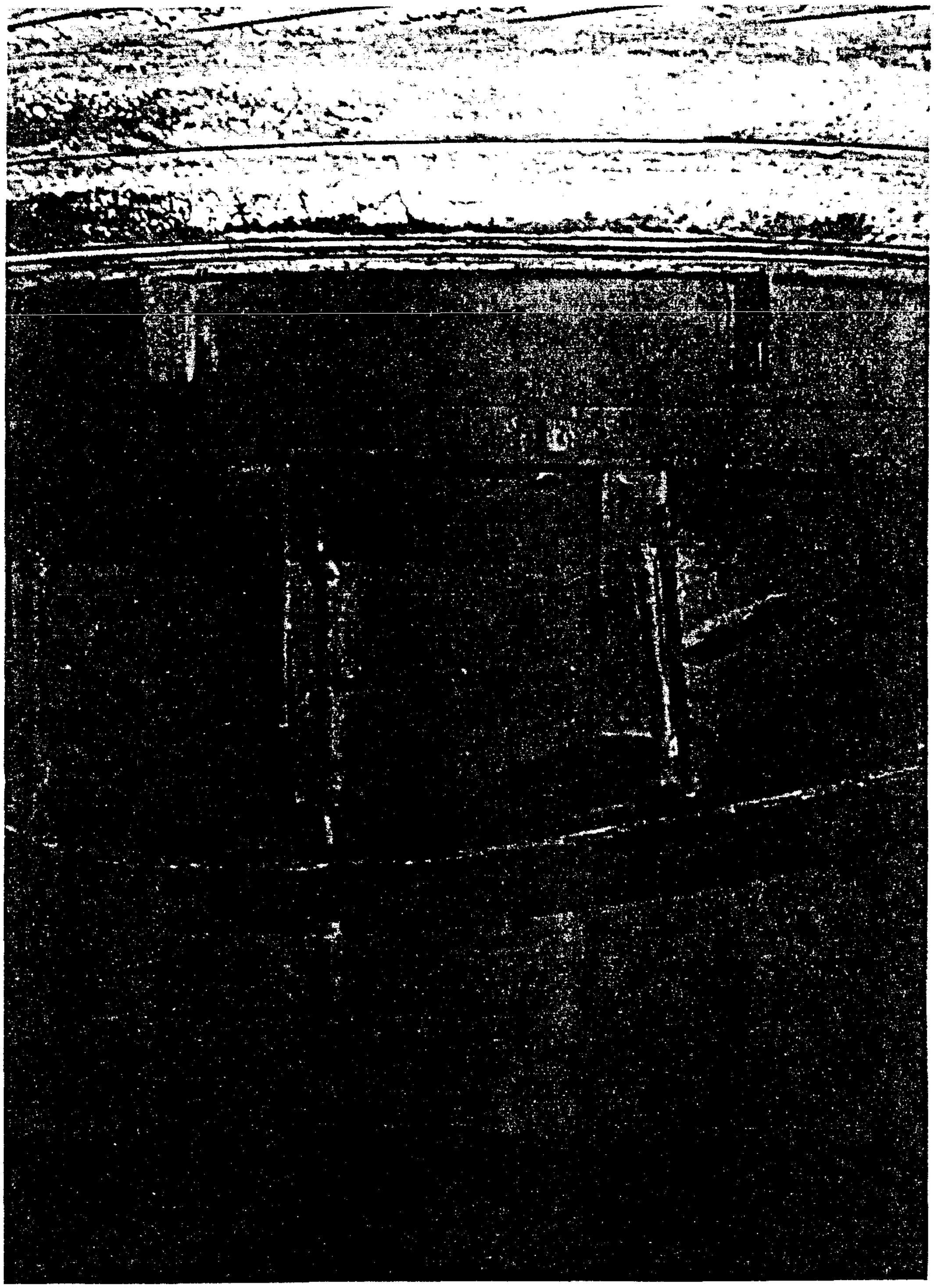

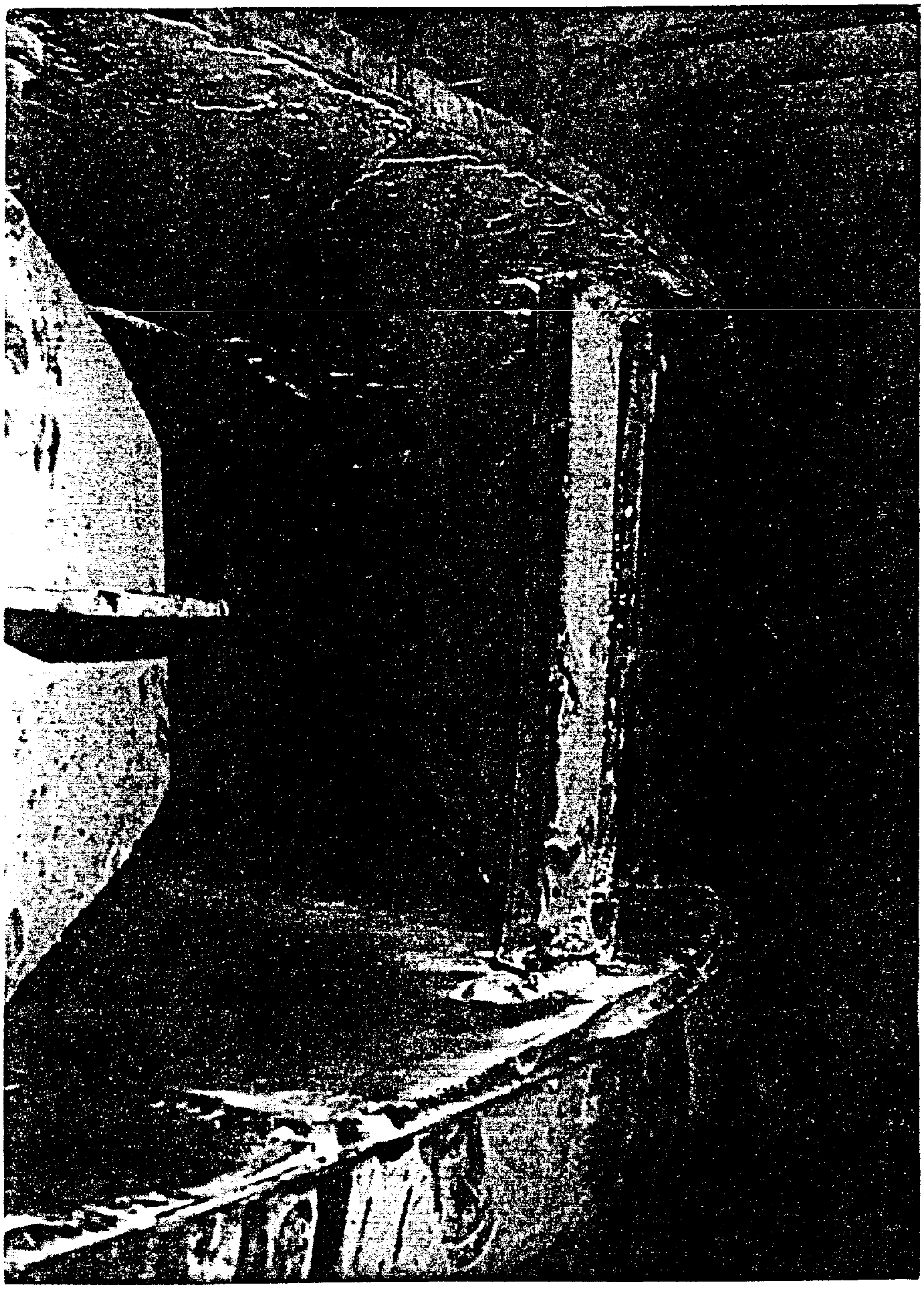

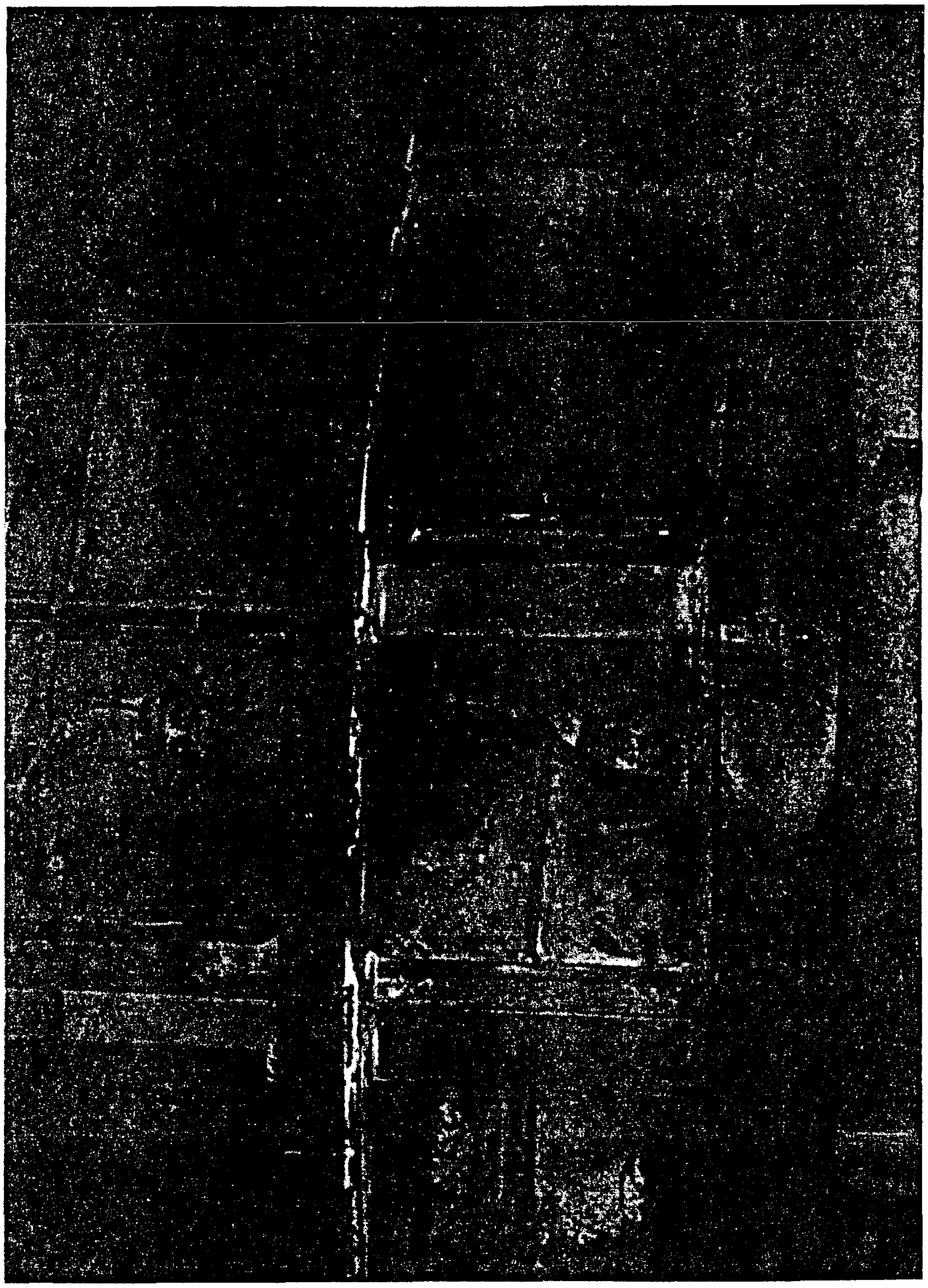

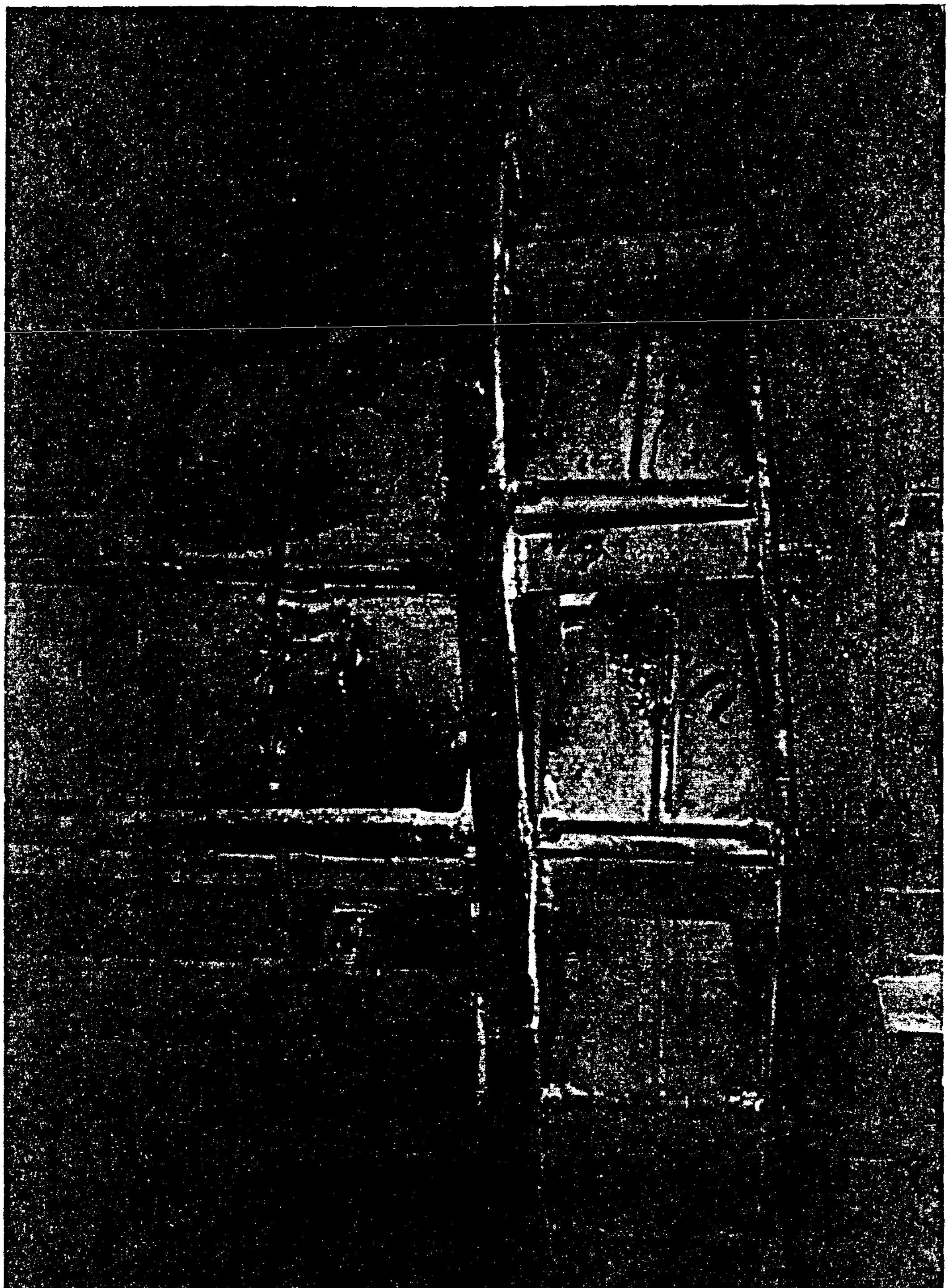

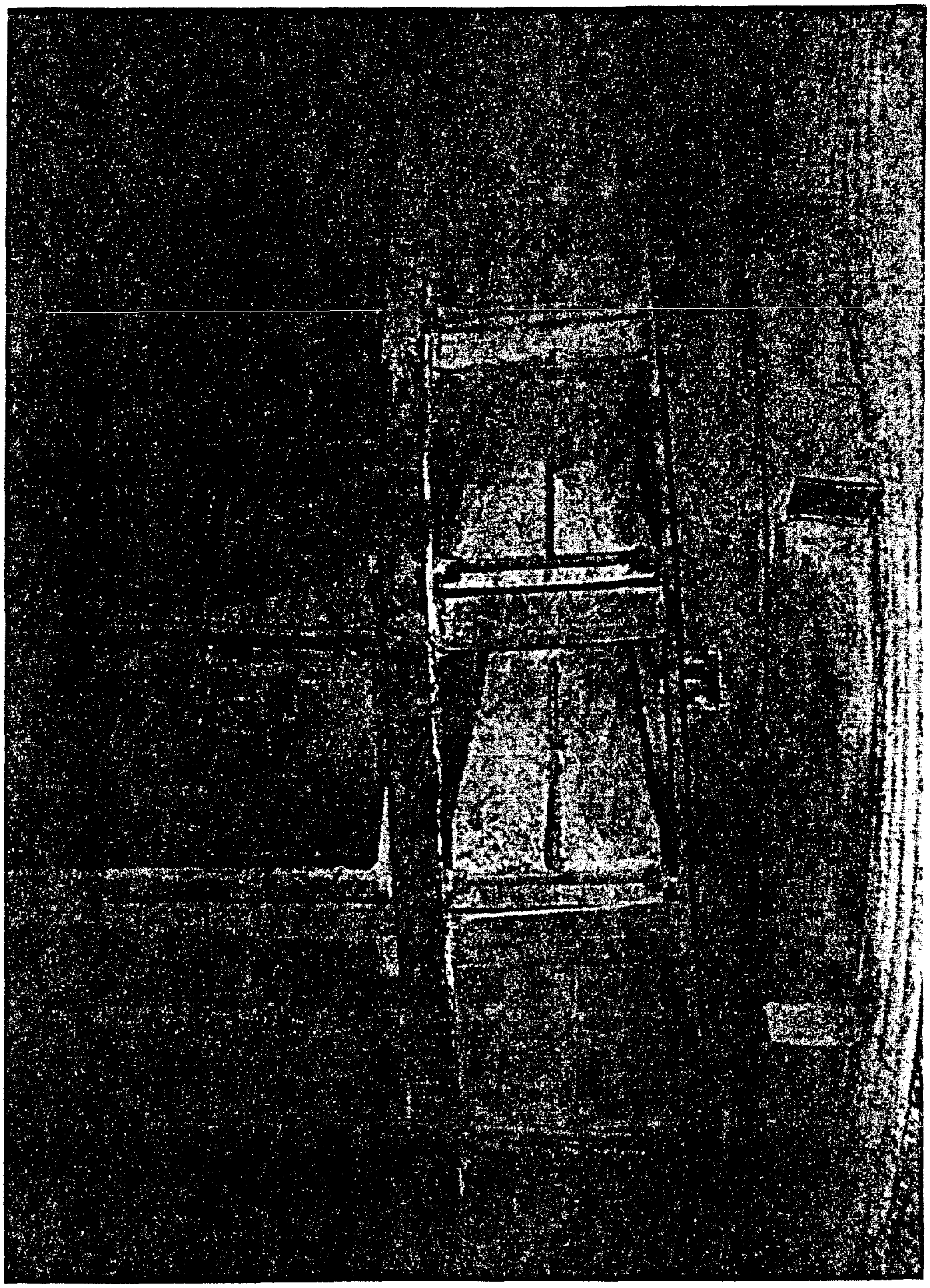

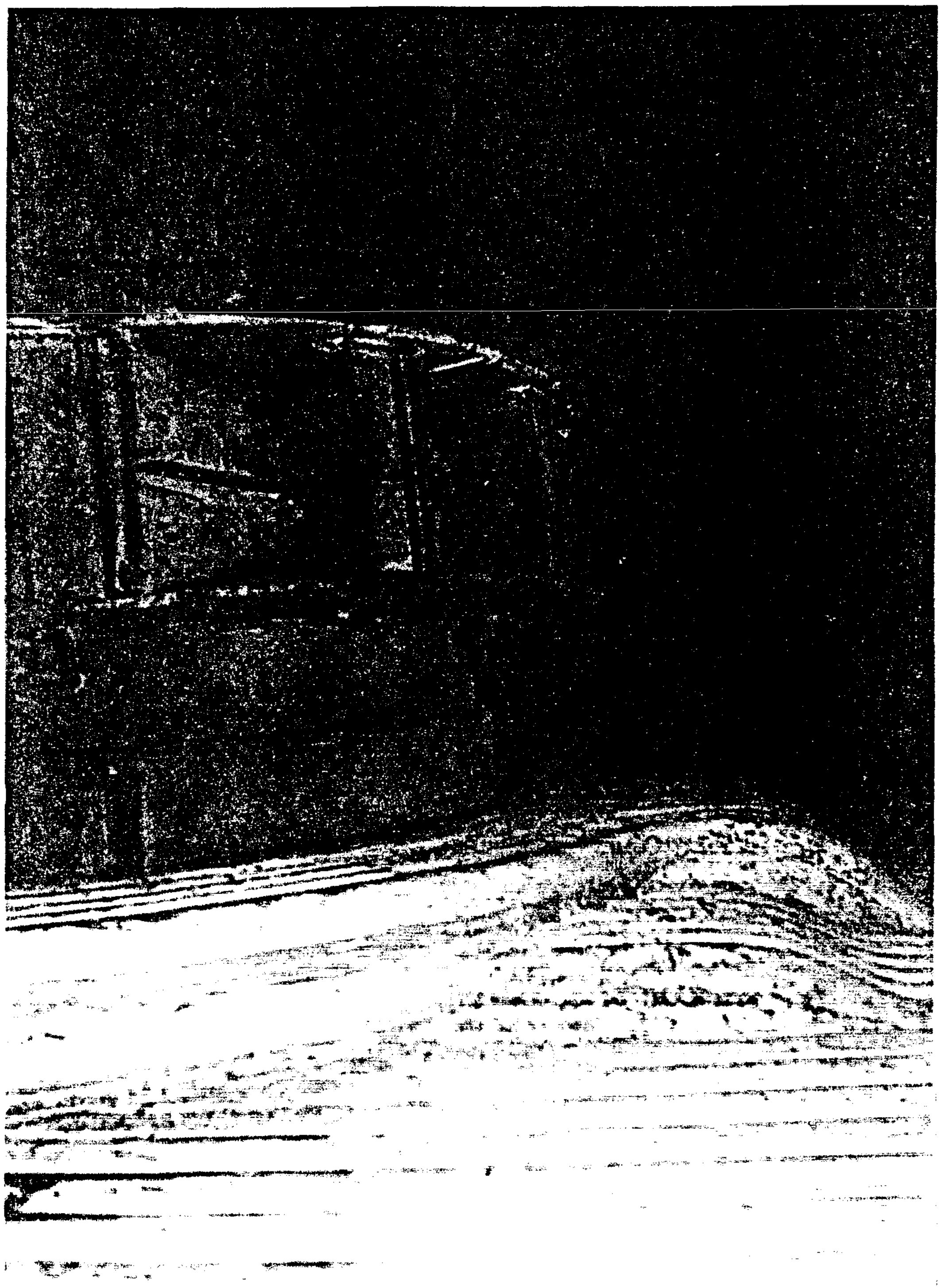

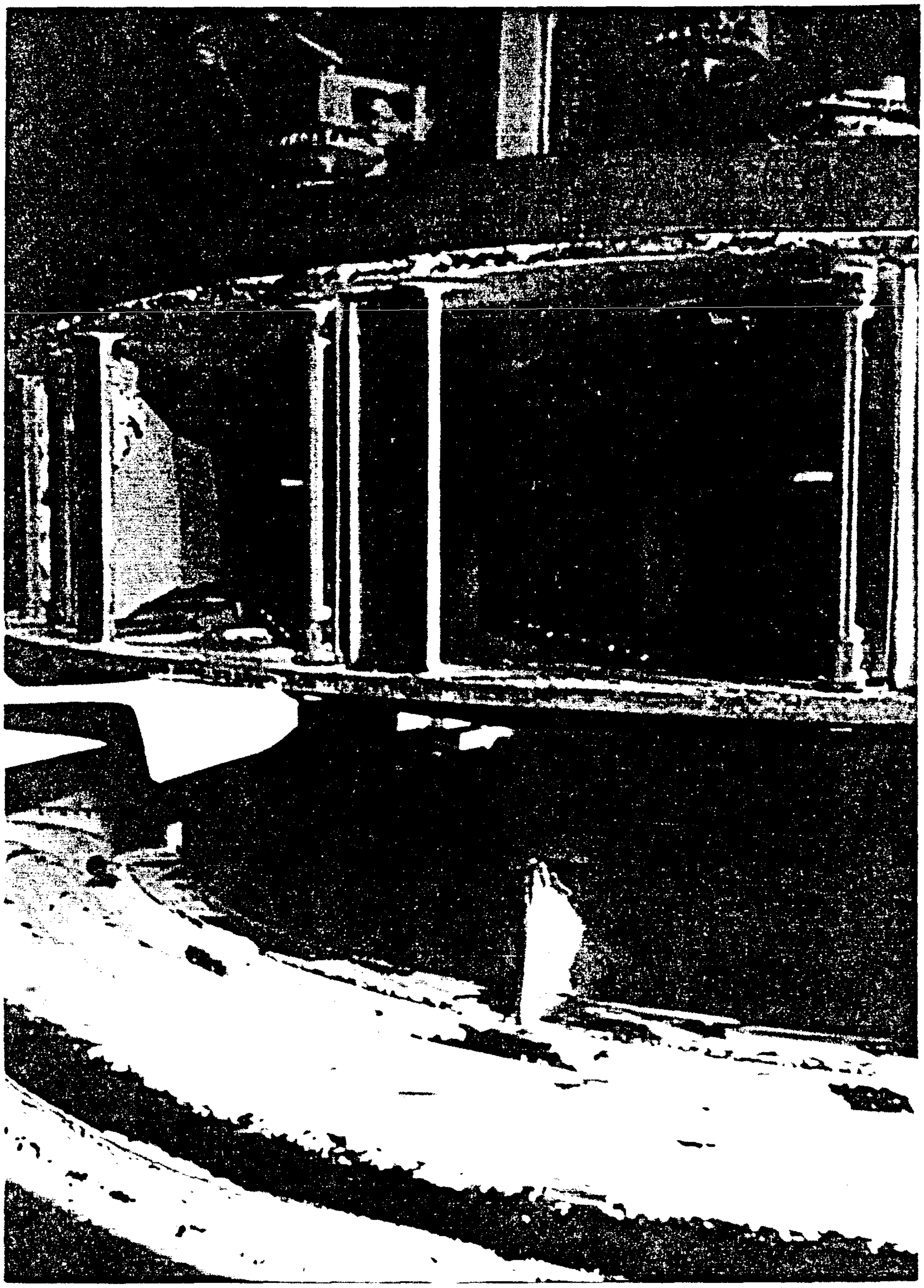

APPENDIX II

AERODYNAMIC CALCULATIONS

- **Baseline Existing Design**
  ΔP = 2.0 inch of water

- **Swirler Design Case (a) No Band**
  ΔP = 1.19 inch of water

- **Swirler Design Case (b) With Band**
  ΔP = 1.99 inch of water

RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54 4/06/89

Baseline

IPP, OUTER REGISTER OPEN 25 DEG (EXISTING)

RADIAL FLOW DAMPER VANE EXIT GEOMETRY
NUMBER OF VANES= 16
THICKNESS,FT= .01042
SPAN LENGTH,FT= .83330
RADIUS,FT= 2.91670
ANGLE (+C.W.LOOKING UPSTREAM),DEG= 65.00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
NUMBER OF VANES= 0
THICKNESS,FT= .00000
ANNULAR SPACE TIP RADIUS,FT= 2.41670
ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT= 1.68750
VANE HUB RADIUS,FT= 1.68740
VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
(.00/1.0000) (.00/ .0000) (

DELTA P EQUALS 2.0 INCH H2O

BURNER SWIRL SYSTEM CONDITIONS
INLET TEMPERATURE,DEG F= 650.00000
INLET PRESSURE,PSFA=2126.62000
EXIT PRESSURE,PSFA=2116.22000
VANE CASCADE DYNAMIC HEAD LOSS,"q"= 1.00000
ANNULAR SPACE DYNAMIC HEAD LOSS,"q"= 1.00000

RADIAL DAMPER VANE EXIT CONDITIONS

R= 2.91670 PT=2126.62000 PS=2122.67500 TT=1109.70000 TS=1109.11100
V= 84.06414 VR= 35.52711 VT= 76.18795 AT= 65.00000 THROAT= 6.31497

FLOW,LBM/SEC= 19.06265
CIRCULATION,SQ FT/SEC=1396.23200

AXIAL ANNULAR SPACE EXIT CONDITIONS

STREAMLINE R= 2.4167 PT=2122.7 PS=2116.2 TT=1109.7 TS=1108.7 RHO= .0360
V= 107.6 VZ= 56.0 VT= 92.0 A= 58.68 B= 58.68 P= .00 TAU= .0000

STREAMTUBE R= 2.3805 DM= 2.1948 DGT= .152E+02 DGX= .382E+01 DSWIRL= 1.643
DGP= -.160E+00 DRECIR= 3.4

STREAMLINE R= 2.3438 PT=2122.7 PS=2115.9 TT=1109.7 TS=1108.7 RHO= .0360
V= 110.1 VZ= 56.0 VT= 94.8 A= 59.44 B= 59.44 P= .00 TAU= .0000

STREAMTUBE R= 2.3076 DM= 2.1284 DGT= .147E+02 DGX= .370E+01 DSWIRL= 1.642
DGP= -.486E+00 DRECIR= 3.0

STREAMLINE R= 2.2709 PT=2122.7 PS=2115.6 TT=1109.7 TS=1108.6 RHO= .0360
V= 112.7 VZ= 56.0 VT= 97.9 A= 60.22 B= 60.22 P= .00 TAU= .0000

STREAMTUBE R= 2.2347 DM= 2.0619 DGT= .142E+02 DGX= .359E+01 DSWIRL= 1.642
DGP= -.823E+00 DRECIR= 2.7

STREAMLINE R= 2.1979 PT=2122.7 PS=2115.2 TT=1109.7 TS=1108.6 RHO= .0360
V= 115.6 VZ= 56.0 VT= 101.1 A= 61.00 B= 61.00 P= .00 TAU= .0000

STREAMTUBE R= 2.1618 DM= 1.9958 DGT= .138E+02 DGX= .348E+01 DSWIRL= 1.640
DGP= -.117E+01 DRECIR= 2.3

STREAMLINE R= 2.1250 PT=2122.7 PS=2114.8 TT=1109.7 TS=1108.5 RHO= .0360
V= 118.7 VZ= 56.1 VT= 104.6 A= 61.80 B= 61.80 P= .00 TAU= .0000

```
STREAMTUBE R= 2.0889 DM= 1.9295 DGT=  .133E+02 DGX=  .336E+01 DSWIRL=  1.640
                                DGP= -.153E+01 DRECIR=    1.9

STREAMLINE R= 2.0521 PT=2122.7 PS=2114.4 TT=1109.7 TS=1108.5 RHO= .0360
  V= 122.0 VZ=  56.1 VT= 108.3  A= 62.62  B= 62.62  P=   .00 TAU= .0000

STREAMTUBE R= 2.0160 DM= 1.8631 DGT=  .129E+02 DGX=  .325E+01 DSWIRL=  1.639
                                DGP= -.191E+01 DRECIR=    1.4

STREAMLINE R= 1.9792 PT=2122.7 PS=2113.9 TT=1109.7 TS=1108.4 RHO= .0360
  V= 125.5 VZ=  56.1 VT= 112.3  A= 63.44  B= 63.44  P=   .00 TAU= .0000

STREAMTUBE R= 1.9431 DM= 1.7972 DGT=  .124E+02 DGX=  .314E+01 DSWIRL=  1.637
                                DGP= -.230E+01 DRECIR=     .9

STREAMLINE R= 1.9063 PT=2122.7 PS=2113.4 TT=1109.7 TS=1108.3 RHO= .0360
  V= 129.4 VZ=  56.2 VT= 116.6  A= 64.27  B= 64.27  P=   .00 TAU= .0000

STREAMTUBE R= 1.8702 DM= 1.7311 DGT=  .120E+02 DGX=  .302E+01 DSWIRL=  1.636
                                DGP= -.272E+01 DRECIR=     .4

STREAMLINE R= 1.8333 PT=2122.7 PS=2112.7 TT=1109.7 TS=1108.2 RHO= .0360
  V= 133.6 VZ=  56.2 VT= 121.2  A= 65.11  B= 65.11  P=   .00 TAU= .0000

STREAMTUBE R= 1.7972 DM= 1.6652 DGT=  .115E+02 DGX=  .291E+01 DSWIRL=  1.635
                                DGP= -.315E+01 DRECIR=    -.3

STREAMLINE R= 1.7604 PT=2122.7 PS=2112.0 TT=1109.7 TS=1108.1 RHO= .0360
  V= 138.2 VZ=  56.3 VT= 126.2  A= 65.97  B= 65.97  P=   .00 TAU= .0000

STREAMTUBE R= 1.7243 DM= 1.5993 DGT=  .110E+02 DGX=  .280E+01 DSWIRL=  1.633
                                DGP= -.360E+01 DRECIR=   -1.0

STREAMLINE R= 1.6875 PT=2122.7 PS=2111.3 TT=1109.7 TS=1108.0 RHO= .0360
  V= 143.2 VZ=  56.3 VT= 131.7  A= 66.83  B= 66.83  P=   .00 TAU= .0000

FLOW,LBM/SEC=  18.96632
SWIRL NUMBER= 1.639  REFERRED TO RADIUS,FT= 2.41670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


AXIAL SWIRL VANE EXIT CONDITIONS


STREAMLINE R= 1.6875 PT=2122.7 PS=2111.3 TT=1109.7 TS=1108.0 RHO= .0360
  V= 143.2 VZ= 143.2 VT=     .0  A=    .00  B=    .00  P=   .00 TAU= .0000

STREAMTUBE R= 1.6874 DM=  .0055 DGT=  .000E+00 DGX=  .243E-01 DSWIRL=   .000
                                DGP= -.526E-02 DRECIR=   18.0

STREAMLINE R= 1.6874 PT=2122.7 PS=2111.3 TT=1109.7 TS=1108.0 RHO= .0360
  V= 143.2 VZ= 143.2 VT=     .0  A=    .00  B=    .00  P=   .00 TAU= .0000

FLOW,LBM/SEC=     .00546
SWIRL NUMBER=  .000  REFERRED TO RADIUS,FT= 1.68750
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


CONVERGED, NUMBER OF FLOW ITERATIONS=        21

SWIRLER TO TOTAL FLOW RATIO=      .000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
```

DGX - INCREMENTAL AXIAL MOMENTUM,LBF
DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
- (NEGATIVE MEANS RECIRCULATION ZONE)

RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54 4/06/89

Baseline

IPP, INNER SPIN OPEN 30 DEG, SLIDE 5 INCH OPEN (EXISTING)

RADIAL FLOW DAMPER VANE EXIT GEOMETRY
NUMBER OF VANES= 0
THICKNESS,FT= .00000
SPAN LENGTH,FT= .41660
RADIUS,FT= 1.66670
ANGLE (+C.W.LOOKING UPSTREAM),DEG= .00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
NUMBER OF VANES= 8
THICKNESS,FT= .01042
ANNULAR SPACE TIP RADIUS,FT= 1.66670
ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT= 1.66660
VANE HUB RADIUS,FT= .91660
VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
(60.00/1.0000) (60.00/ .0000) (

DELTA P EQUALS 2.0 INCH H2O (OUTER REGISTER OPEN 25 DEG)

BURNER SWIRL SYSTEM CONDITIONS
INLET TEMPERATURE,DEG F= 650.00000
INLET PRESSURE,PSFA=2126.62000
EXIT PRESSURE,PSFA=2111.30000
VANE CASCADE DYNAMIC HEAD LOSS,"q"= 1.00000
ANNULAR SPACE DYNAMIC HEAD LOSS,"q"= 1.00000

RADIAL DAMPER VANE EXIT CONDITIONS

R= 1.66670 PT=2126.62000 PS=2121.14800 TT=1109.70000 TS=1108.88300
V= 99.00971 VR= 99.00971 VT= .00000 AT= .00000 THROAT= 4.36271

FLOW,LBM/SEC= 15.50266
CIRCULATION,SQ FT/SEC= .00000

AXIAL ANNULAR SPACE EXIT CONDITIONS

STREAMLINE R= 1.6667 PT=2121.1 PS=2111.3 TT=1109.7 TS=1108.2 RHO= .0360
V= 133.0 VZ= 133.0 VT= .0 A= .00 B= .00 P= .00 TAU= .0000

STREAMTUBE R= 1.6666 DM= .0050 DGT= .000E+00 DGX= .207E-01 DSWIRL= .000
DGP= .000E+00 DRECIR= 19.8 (14.9)

STREAMLINE R= 1.6666 PT=2121.1 PS=2111.3 TT=1109.7 TS=1108.2 RHO= .0360
V= 133.0 VZ= 133.0 VT= .0 A= .00 B= .00 P= .00 TAU= .0000

FLOW,LBM/SEC= .00501
SWIRL NUMBER= .000 REFERRED TO RADIUS,FT= 1.66670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA= 2111.3 (2116.22)

AXIAL SWIRL VANE EXIT CONDITIONS

STREAMLINE R= 1.6666 PT=2121.1 PS=2111.3 TT=1109.7 TS=1108.2 RHO= .0360
V= 133.0 VZ= 66.5 VT= 115.2 A= 60.00 B= 60.00 P= .00 TAU= .0159

STREAMTUBE R= 1.5934 DM= 3.5842 DGT= .208E+02 DGX= .753E+01 DSWIRL= 1.655
DGP= -.477E+00 DRECIR= 4.7 (-.22)

STREAMLINE R= 1.5166 PT=2121.1 PS=2110.6 TT=1109.7 TS=1108.1 RHO= .0360
V= 137.5 VZ= 68.7 VT= 119.1 A= 60.00 B= 60.00 P= .00 TAU= .0175

STREAMTUBE R= 1.4435 DM= 3.3537 DGT= .182E+02 DGX= .729E+01 DSWIRL= 1.500

```
                              DGP= -.141E+01 DRECIR=   4.3 (-.62)

STREAMLINE R= 1.3666 PT=2121.1 PS=2109.8 TT=1109.7 TS=1108.0 RHO= .0360
  V= 142.5 VZ=  71.3 VT= 123.4  A= 60.00  B= 60.00  P=   .00 TAU= .0194

STREAMTUBE R= 1.2938 DM= 3.1134 DGT=  .157E+02 DGX=  .703E+01 DSWIRL=  1.344
                              DGP= -.230E+01 DRECIR=   3.9 (-1.02)

STREAMLINE R= 1.2166 PT=2121.1 PS=2108.9 TT=1109.7 TS=1107.9 RHO= .0360
  V= 148.3 VZ=  74.2 VT= 128.4  A= 60.00  B= 60.00  P=   .00 TAU= .0218

STREAMTUBE R= 1.1441 DM= 2.8617 DGT=  .133E+02 DGX=  .674E+01 DSWIRL=  1.188
                              DGP= -.314E+01 DRECIR=   3.3 (-1.62)

STREAMLINE R= 1.0666 PT=2121.1 PS=2107.8 TT=1109.7 TS=1107.7 RHO= .0360
  V= 155.1 VZ=  77.5 VT= 134.3  A= 60.00  B= 60.00  P=   .00 TAU= .0249

STREAMTUBE R=  .9944 DM= 2.5962 DGT=  .110E+02 DGX=  .641E+01 DSWIRL=  1.033
                              DGP= -.390E+01 DRECIR=   2.7 (-2.22)

STREAMLINE R=  .9166 PT=2121.1 PS=2106.4 TT=1109.7 TS=1107.5 RHO= .0360
  V= 163.1 VZ=  81.6 VT= 141.3  A= 60.00  B= 60.00  P=   .00 TAU= .0289

FLOW,LBM/SEC=  15.50926
SWIRL NUMBER= 1.356  REFERRED TO RADIUS,FT= 1.66660
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2111.3 (2116.22)


CONVERGED, NUMBER OF FLOW ITERATIONS=         6

SWIRLER TO TOTAL FLOW RATIO=     1.000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
    DGX - INCREMENTAL AXIAL MOMENTUM,LBF
    DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
    DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
    DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
           - (NEGATIVE MEANS RECIRCULATION ZONE)
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Case A

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RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54  4/06/89


IPP, OUTER REGISTER OPEN 34 DEG (EXISTING)


RADIAL FLOW DAMPER VANE EXIT GEOMETRY
    NUMBER OF VANES=        16
    THICKNESS,FT=    .01042
    SPAN LENGTH,FT=    .83330
    RADIUS,FT=   2.91670
    ANGLE (+C.W.LOOKING UPSTREAM),DEG=  56.00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
    NUMBER OF VANES=         0
    THICKNESS,FT=    .00000
    ANNULAR SPACE TIP RADIUS,FT=   2.41670
    ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT=   1.68750
    VANE HUB RADIUS,FT=   1.68740
    VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
    (   .00/1.0000)    (   .00/ .0000)    (


DELTA P EQUALS 1.19 INCH H2O


BURNER SWIRL SYSTEM CONDITIONS
    INLET TEMPERATURE,DEG F= 650.00000
    INLET PRESSURE,PSFA=2122.42000
    EXIT PRESSURE,PSFA=2116.22000
    VANE CASCADE DYNAMIC HEAD LOSS,"q"=   1.00000
    ANNULAR SPACE DYNAMIC HEAD LOSS,"q"=   1.00000


RADIAL DAMPER VANE EXIT CONDITIONS


R=   2.91670  PT=2122.42000  PS=2120.19200  TT=1109.70000  TS=1109.36700
V=  63.22945  VR=  35.35750  VT=  52.41956  AT=  56.00000  THROAT=   8.40062

FLOW,LBM/SEC=  19.04467
CIRCULATION,SQ FT/SEC= 960.64870


AXIAL ANNULAR SPACE EXIT CONDITIONS


STREAMLINE R= 2.4167 PT=2120.2 PS=2116.2 TT=1109.7 TS=1109.1 RHO= .0359
  V=  84.5 VZ=  56.0 VT=  63.3  A= 48.50  B= 48.50  P=   .00 TAU= .0000

STREAMTUBE R= 2.3805 DM= 2.1906 DGT=  .104E+02 DGX=  .381E+01 DSWIRL=  1.130
                                DGP= -.758E-01 DRECIR=    3.4

STREAMLINE R= 2.3438 PT=2120.2 PS=2116.1 TT=1109.7 TS=1109.1 RHO= .0359
  V=  86.0 VZ=  56.0 VT=  65.2  A= 49.37  B= 49.37  P=   .00 TAU= .0000

STREAMTUBE R= 2.3076 DM= 2.1237 DGT=  .101E+02 DGX=  .369E+01 DSWIRL=  1.130
                                DGP= -.230E+00 DRECIR=    3.3

STREAMLINE R= 2.2709 PT=2120.2 PS=2115.9 TT=1109.7 TS=1109.1 RHO= .0359
  V=  87.6 VZ=  56.0 VT=  67.3  A= 50.25  B= 50.25  P=   .00 TAU= .0000

STREAMTUBE R= 2.2347 DM= 2.0568 DGT=  .977E+01 DGX=  .358E+01 DSWIRL=  1.130
                                DGP= -.389E+00 DRECIR=    3.1

STREAMLINE R= 2.1979 PT=2120.2 PS=2115.8 TT=1109.7 TS=1109.0 RHO= .0359
  V=  89.3 VZ=  56.0 VT=  69.6  A= 51.17  B= 51.17  P=   .00 TAU= .0000

STREAMTUBE R= 2.1618 DM= 1.9899 DGT=  .945E+01 DGX=  .346E+01 DSWIRL=  1.130
                                DGP= -.553E+00 DRECIR=    2.9

STREAMLINE R= 2.1250 PT=2120.2 PS=2115.6 TT=1109.7 TS=1109.0 RHO= .0359
  V=  91.2 VZ=  56.0 VT=  71.9  A= 52.11  B= 52.11  P=   .00 TAU= .0000
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STREAMTUBE R= 2.0889 DM= 1.9230 DGT=  .914E+01 DGX=  .335E+01 DSWIRL=  1.130
                                DGP= -.724E+00 DRECIR=    2.7

STREAMLINE R= 2.0521 PT=2120.2 PS=2115.4 TT=1109.7 TS=1109.0 RHO= .0359
  V=  93.2 VZ=  56.0 VT=  74.5  A= 53.07  B= 53.07  P=   .00 TAU= .0000

STREAMTUBE R= 2.0160 DM= 1.8561 DGT=  .882E+01 DGX=  .323E+01 DSWIRL=  1.130
                                DGP= -.903E+00 DRECIR=    2.5

STREAMLINE R= 1.9792 PT=2120.2 PS=2115.1 TT=1109.7 TS=1108.9 RHO= .0359
  V=  95.4 VZ=  56.0 VT=  77.3  A= 54.05  B= 54.05  P=   .00 TAU= .0000

STREAMTUBE R= 1.9431 DM= 1.7892 DGT=  .850E+01 DGX=  .311E+01 DSWIRL=  1.129
                                DGP= -.109E+01 DRECIR=    2.3

STREAMLINE R= 1.9063 PT=2120.2 PS=2114.9 TT=1109.7 TS=1108.9 RHO= .0359
  V=  97.8 VZ=  56.0 VT=  80.2  A= 55.07  B= 55.07  P=   .00 TAU= .0000

STREAMTUBE R= 1.8702 DM= 1.7224 DGT=  .818E+01 DGX=  .300E+01 DSWIRL=  1.129
                                DGP= -.128E+01 DRECIR=    2.0

STREAMLINE R= 1.8333 PT=2120.2 PS=2114.6 TT=1109.7 TS=1108.9 RHO= .0359
  V= 100.5 VZ=  56.0 VT=  83.4  A= 56.10  B= 56.10  P=   .00 TAU= .0000

STREAMTUBE R= 1.7972 DM= 1.6557 DGT=  .787E+01 DGX=  .288E+01 DSWIRL=  1.129
                                DGP= -.149E+01 DRECIR=    1.7

STREAMLINE R= 1.7604 PT=2120.2 PS=2114.2 TT=1109.7 TS=1108.8 RHO= .0359
  V= 103.4 VZ=  56.1 VT=  86.8  A= 57.16  B= 57.16  P=   .00 TAU= .0000

STREAMTUBE R= 1.7243 DM= 1.5891 DGT=  .755E+01 DGX=  .277E+01 DSWIRL=  1.128
                                DGP= -.170E+01 DRECIR=    1.3

STREAMLINE R= 1.6875 PT=2120.2 PS=2113.9 TT=1109.7 TS=1108.8 RHO= .0359
  V= 106.6 VZ=  56.1 VT=  90.6  A= 58.25  B= 58.25  P=   .00 TAU= .0000

FLOW,LBM/SEC=  18.89652
SWIRL NUMBER= 1.130  REFERRED TO RADIUS,FT= 2.41670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


AXIAL SWIRL VANE EXIT CONDITIONS


STREAMLINE R= 1.6875 PT=2120.2 PS=2113.9 TT=1109.7 TS=1108.8 RHO= .0359
  V= 106.6 VZ= 106.6 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

STREAMTUBE R= 1.6874 DM=  .0041 DGT=  .000E+00 DGX=  .134E-01 DSWIRL=   .000
                                DGP= -.249E-02 DRECIR=   10.3

STREAMLINE R= 1.6874 PT=2120.2 PS=2113.9 TT=1109.7 TS=1108.8 RHO= .0359
  V= 106.6 VZ= 106.6 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

FLOW,LBM/SEC=    .00405
SWIRL NUMBER=  .000  REFERRED TO RADIUS,FT= 1.68750
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


CONVERGED, NUMBER OF FLOW ITERATIONS=        29

SWIRLER TO TOTAL FLOW RATIO=      .000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
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DGX - INCREMENTAL AXIAL MOMENTUM,LBF
DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
       - (NEGATIVE MEANS RECIRCULATION ZONE)
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Case A

RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54 4/06/89

IPP, INNER SPIN OPEN 90 DEG, SLIDE 10 INCH OPEN, 40 INCH SWIRLER

```
RADIAL FLOW DAMPER VANE EXIT GEOMETRY
    NUMBER OF VANES=        0
    THICKNESS,FT=     .00000
    SPAN LENGTH,FT=     .83330
    RADIUS,FT=   1.66670
    ANGLE (+C.W.LOOKING UPSTREAM),DEG=     .00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
    NUMBER OF VANES=       40
    THICKNESS,FT=     .01042
    ANNULAR SPACE TIP RADIUS,FT=   1.66670
    ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT=   1.66660
    VANE HUB RADIUS,FT=     .91660
    VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
    ( 64.00/1.0000)     ( 40.00/ .1111)     (   .00/ .0000)     (

DELTA P EQUALS 1.19 INCH H2O (OUTER REGISTER OPEN 34 DEG)

BURNER SWIRL SYSTEM CONDITIONS
    INLET TEMPERATURE,DEG F= 650.00000
    INLET PRESSURE,PSFA=2122.42000
    EXIT PRESSURE,PSFA=2113.90000
    VANE CASCADE DYNAMIC HEAD LOSS,"q"=   1.00000
    ANNULAR SPACE DYNAMIC HEAD LOSS,"q"=   1.00000

RADIAL DAMPER VANE EXIT CONDITIONS

R=   1.66670  PT=2122.42000  PS=2121.05900  TT=1109.70000  TS=1109.49700
V=  49.39742  VR=  49.39742  VT=    .00000  AT=    .00000  THROAT=   8.72646

FLOW,LBM/SEC=  15.46160
CIRCULATION,SQ FT/SEC=    .00000

AXIAL ANNULAR SPACE EXIT CONDITIONS

STREAMLINE R= 1.6667 PT=2121.1 PS=2113.9 TT=1109.7 TS=1108.6 RHO= .0359
  V= 113.4 VZ= 113.4 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

STREAMTUBE R= 1.6666 DM=  .0043 DGT=  .000E+00 DGX=  .150E-01 DSWIRL=   .000
                              DGP=  .000E+00 DRECIR=   14.3  (12.0)

STREAMLINE R= 1.6666 PT=2121.1 PS=2113.9 TT=1109.7 TS=1108.6 RHO= .0359
  V= 113.4 VZ= 113.4 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

FLOW,LBM/SEC=    .00426
SWIRL NUMBER=  .000  REFERRED TO RADIUS,FT= 1.66670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2113.9 (2116.22)

AXIAL SWIRL VANE EXIT CONDITIONS

STREAMLINE R= 1.6666 PT=2121.1 PS=2113.9 TT=1109.7 TS=1108.6 RHO= .0359
  V= 113.4 VZ=  49.7 VT= 101.9  A= 64.00  B= 64.00  P=   .00 TAU= .0908

STREAMTUBE R= 1.6255 DM= 1.4700 DGT=  .753E+01 DGX=  .242E+01 DSWIRL=  1.866
                              DGP= -.120E+00 DRECIR=    2.7  (.38)

STREAMLINE R= 1.5833 PT=2121.1 PS=2113.6 TT=1109.7 TS=1108.6 RHO= .0359
  V= 115.7 VZ=  56.1 VT= 101.2  A= 61.00  B= 61.00  P=   .00 TAU= .0864

STREAMTUBE R= 1.5422 DM= 1.5699 DGT=  .756E+01 DGX=  .290E+01 DSWIRL=  1.566
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                              DGP= -.352E+00 DRECIR=    3.2  (.88)

STREAMLINE R= 1.4999 PT=2121.1 PS=2113.3 TT=1109.7 TS=1108.5 RHO= .0359
  V= 118.0 VZ=  62.5 VT= 100.1  A= 58.00  B= 58.00  P=   .00 TAU= .0835

STREAMTUBE R= 1.4589 DM= 1.6513 DGT=  .743E+01 DGX=  .338E+01 DSWIRL= 1.319
                              DGP= -.566E+00 DRECIR=    3.7  (1.38)

STREAMLINE R= 1.4166 PT=2121.1 PS=2113.0 TT=1109.7 TS=1108.5 RHO= .0359
  V= 120.3 VZ=  69.0 VT=  98.6  A= 55.00  B= 55.00  P=   .00 TAU= .0816

STREAMTUBE R= 1.3756 DM= 1.7134 DGT=  .715E+01 DGX=  .385E+01 DSWIRL= 1.113
                              DGP= -.760E+00 DRECIR=    4.3  (1.98)

STREAMLINE R= 1.3333 PT=2121.1 PS=2112.7 TT=1109.7 TS=1108.4 RHO= .0359
  V= 122.7 VZ=  75.5 VT=  96.7  A= 52.00  B= 52.00  P=   .00 TAU= .0808

STREAMTUBE R= 1.2923 DM= 1.7554 DGT=  .673E+01 DGX=  .430E+01 DSWIRL=  .939
                              DGP= -.931E+00 DRECIR=    5.0  (2.68)

STREAMLINE R= 1.2499 PT=2121.1 PS=2112.4 TT=1109.7 TS=1108.4 RHO= .0359
  V= 125.1 VZ=  82.1 VT=  94.4  A= 49.00  B= 49.00  P=   .00 TAU= .0809

STREAMTUBE R= 1.2090 DM= 1.7764 DGT=  .621E+01 DGX=  .471E+01 DSWIRL=  .791
                              DGP= -.108E+01 DRECIR=    5.7  (3.38)

STREAMLINE R= 1.1666 PT=2121.1 PS=2112.0 TT=1109.7 TS=1108.3 RHO= .0359
  V= 127.4 VZ=  88.5 VT=  91.7  A= 46.00  B= 46.00  P=   .00 TAU= .0819

STREAMTUBE R= 1.1257 DM= 1.7758 DGT=  .560E+01 DGX=  .506E+01 DSWIRL=  .664
                              DGP= -.120E+01 DRECIR=    6.6  (4.28)

STREAMLINE R= 1.0833 PT=2121.1 PS=2111.7 TT=1109.7 TS=1108.3 RHO= .0359
  V= 129.8 VZ=  94.9 VT=  88.5  A= 43.00  B= 43.00  P=   .00 TAU= .0837

STREAMTUBE R= 1.0424 DM= 1.7533 DGT=  .493E+01 DGX=  .534E+01 DSWIRL=  .554
                              DGP= -.129E+01 DRECIR=    7.4  (5.08)

STREAMLINE R=  .9999 PT=2121.1 PS=2111.4 TT=1109.7 TS=1108.2 RHO= .0359
  V= 132.1 VZ= 101.2 VT=  84.9  A= 40.00  B= 40.00  P=   .00 TAU= .0866

STREAMTUBE R=  .9592 DM= 1.9414 DGT=  .229E+01 DGX=  .721E+01 DSWIRL=  .191
                              DGP= -.136E+01 DRECIR=   11.7  (9.38)

STREAMLINE R=  .9166 PT=2121.1 PS=2111.0 TT=1109.7 TS=1108.2 RHO= .0359
  V= 134.4 VZ= 134.4 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0724

FLOW,LBM/SEC=  15.40694
SWIRL NUMBER=  .849  REFERRED TO RADIUS,FT= 1.66660
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2113.9 (2116.22)


CONVERGED, NUMBER OF FLOW ITERATIONS=         7

SWIRLER TO TOTAL FLOW RATIO=     1.000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
    DGX - INCREMENTAL AXIAL MOMENTUM,LBF
    DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
    DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
    DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
           - (NEGATIVE MEANS RECIRCULATION ZONE)
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RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54  4/06/89


IPP, OUTER REGISTER OPEN 40 DEG (EXISTING) W/BAND 1304 SQ IN OPEN INLET


RADIAL FLOW DAMPER VANE EXIT GEOMETRY
    NUMBER OF VANES=        16
    THICKNESS,FT=     .01042
    SPAN LENGTH,FT=     .83330
    RADIUS,FT=   2.91670
    ANGLE (+C.W.LOOKING UPSTREAM),DEG=  50.00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
    NUMBER OF VANES=         0
    THICKNESS,FT=     .00000
    ANNULAR SPACE TIP RADIUS,FT=   2.41670
    ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT=   1.68750
    VANE HUB RADIUS,FT=   1.68740
    VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
    (    .00/1.0000)    (    .00/ .0000)    (


DELTA P:TOTAL=1.99 INCH H2O; BAND=1.05 AND REG TO FURN=0.94


BURNER SWIRL SYSTEM CONDITIONS
    INLET TEMPERATURE,DEG F= 650.00000
    INLET PRESSURE,PSFA=2121.11000
    EXIT PRESSURE,PSFA=2116.22000
    VANE CASCADE DYNAMIC HEAD LOSS,"q"=   1.00000
    ANNULAR SPACE DYNAMIC HEAD LOSS,"q"=   1.00000


RADIAL DAMPER VANE EXIT CONDITIONS


R=   2.91670  PT=2121.11000  PS=2119.41900  TT=1109.70000  TS=1109.44700
V=  55.10514  VR=  35.42093  VT=  42.21296  AT=  50.00000  THROAT=   9.67721

FLOW,LBM/SEC=  19.10859
CIRCULATION,SQ FT/SEC= 773.60100


AXIAL ANNULAR SPACE EXIT CONDITIONS


STREAMLINE R= 2.4167 PT=2119.4 PS=2116.2 TT=1109.7 TS=1109.2 RHO= .0359
  V=  75.8 VZ=  56.1 VT=  50.9  A= 42.22  B= 42.22  P=   .00 TAU= .0000

STREAMTUBE R= 2.3805 DM= 2.1960 DGT=  .840E+01 DGX=  .383E+01 DSWIRL=   .907
                                DGP= -.490E-01 DRECIR=    3.5

STREAMLINE R= 2.3438 PT=2119.4 PS=2116.1 TT=1109.7 TS=1109.2 RHO= .0359
  V=  76.9 VZ=  56.2 VT=  52.5  A= 43.09  B= 43.09  P=   .00 TAU= .0000

STREAMTUBE R= 2.3076 DM= 2.1288 DGT=  .815E+01 DGX=  .372E+01 DSWIRL=   .907
                                DGP= -.149E+00 DRECIR=    3.4

STREAMLINE R= 2.2709 PT=2119.4 PS=2116.0 TT=1109.7 TS=1109.2 RHO= .0359
  V=  78.1 VZ=  56.1 VT=  54.2  A= 44.00  B= 44.00  P=   .00 TAU= .0000

STREAMTUBE R= 2.2347 DM= 2.0617 DGT=  .789E+01 DGX=  .360E+01 DSWIRL=   .907
                                DGP= -.252E+00 DRECIR=    3.3

STREAMLINE R= 2.1979 PT=2119.4 PS=2115.9 TT=1109.7 TS=1109.2 RHO= .0359
  V=  79.3 VZ=  56.2 VT=  56.0  A= 44.92  B= 44.92  P=   .00 TAU= .0000

STREAMTUBE R= 2.1618 DM= 1.9947 DGT=  .763E+01 DGX=  .348E+01 DSWIRL=   .907
                                DGP= -.359E+00 DRECIR=    3.2

STREAMLINE R= 2.1250 PT=2119.4 PS=2115.8 TT=1109.7 TS=1109.2 RHO= .0359
  V=  80.7 VZ=  56.2 VT=  57.9  A= 45.89  B= 45.89  P=   .00 TAU= .0000
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STREAMTUBE R= 2.0889 DM= 1.9274 DGT=  .737E+01 DGX=  .336E+01 DSWIRL=   .907
                                DGP= -.470E+00 DRECIR=   3.0

STREAMLINE R= 2.0521 PT=2119.4 PS=2115.7 TT=1109.7 TS=1109.1 RHO= .0359
  V=  82.2 VZ=  56.2 VT=  60.0  A= 46.89  B= 46.89  P=   .00 TAU= .0000

STREAMTUBE R= 2.0160 DM= 1.8603 DGT=  .712E+01 DGX=  .325E+01 DSWIRL=   .907
                                DGP= -.585E+00 DRECIR=   2.9

STREAMLINE R= 1.9792 PT=2119.4 PS=2115.5 TT=1109.7 TS=1109.1 RHO= .0359
  V=  83.8 VZ=  56.2 VT=  62.2  A= 47.92  B= 47.92  P=   .00 TAU= .0000

STREAMTUBE R= 1.9431 DM= 1.7934 DGT=  .686E+01 DGX=  .313E+01 DSWIRL=   .907
                                DGP= -.706E+00 DRECIR=   2.7

STREAMLINE R= 1.9063 PT=2119.4 PS=2115.3 TT=1109.7 TS=1109.1 RHO= .0359
  V=  85.6 VZ=  56.2 VT=  64.6  A= 48.98  B= 48.98  P=   .00 TAU= .0000

STREAMTUBE R= 1.8702 DM= 1.7261 DGT=  .660E+01 DGX=  .301E+01 DSWIRL=   .907
                                DGP= -.832E+00 DRECIR=   2.5

STREAMLINE R= 1.8333 PT=2119.4 PS=2115.2 TT=1109.7 TS=1109.1 RHO= .0359
  V=  87.6 VZ=  56.2 VT=  67.2  A= 50.09  B= 50.09  P=   .00 TAU= .0000

STREAMTUBE R= 1.7972 DM= 1.6588 DGT=  .635E+01 DGX=  .290E+01 DSWIRL=   .907
                                DGP= -.964E+00 DRECIR=   2.3

STREAMLINE R= 1.7604 PT=2119.4 PS=2114.9 TT=1109.7 TS=1109.0 RHO= .0359
  V=  89.7 VZ=  56.2 VT=  69.9  A= 51.22  B= 51.22  P=   .00 TAU= .0000

STREAMTUBE R= 1.7243 DM= 1.5918 DGT=  .609E+01 DGX=  .278E+01 DSWIRL=   .907
                                DGP= -.110E+01 DRECIR=   2.1

STREAMLINE R= 1.6875 PT=2119.4 PS=2114.7 TT=1109.7 TS=1109.0 RHO= .0359
  V=  92.1 VZ=  56.2 VT=  73.0  A= 52.39  B= 52.39  P=   .00 TAU= .0000

FLOW,LBM/SEC=  18.93924
SWIRL NUMBER=  .907  REFERRED TO RADIUS,FT= 2.41670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


AXIAL SWIRL VANE EXIT CONDITIONS


STREAMLINE R= 1.6875 PT=2119.4 PS=2114.7 TT=1109.7 TS=1109.0 RHO= .0359
  V=  92.1 VZ=  92.1 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

STREAMTUBE R= 1.6874 DM=  .0035 DGT=  .000E+00 DGX=  .100E-01 DSWIRL=   .000
                                DGP= -.161E-02 DRECIR=   7.9

STREAMLINE R= 1.6874 PT=2119.4 PS=2114.7 TT=1109.7 TS=1109.0 RHO= .0359
  V=  92.1 VZ=  92.1 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

FLOW,LBM/SEC=     .00350
SWIRL NUMBER=  .000  REFERRED TO RADIUS,FT= 1.68750
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2116.2


CONVERGED, NUMBER OF FLOW ITERATIONS=       34

SWIRLER TO TOTAL FLOW RATIO=      .000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
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DGX - INCREMENTAL AXIAL MOMENTUM,LBF
DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
       - (NEGATIVE MEANS RECIRCULATION ZONE)
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RADIAL AND AXIAL BURNER AIR SWIRL SYSTEM
CONSTANT DENSITY, ADIABATIC, ISENTROPIC
FREE VORTEX IN ANNULAR SPACE, FORCED VORTEX IN SWIRL VANE
LINEAR SWIRL VANE EXIT ANGLE VERSUS RADIUS
PLUME OUTER (TIP) STREAMLINE EQUAL TO EXIT PRESSURE
VERSION 1.54  4/06/89


IPP, INNER SPIN OPEN 90 DEG, SLIDE 5 INCH OPEN, 40 INCH SWIRLER


RADIAL FLOW DAMPER VANE EXIT GEOMETRY
    NUMBER OF VANES=         0
    THICKNESS,FT=    .00000
    SPAN LENGTH,FT=    .41660
    RADIUS,FT=   1.66670
    ANGLE (+C.W.LOOKING UPSTREAM),DEG=    .00000

AXIAL FLOW ANNULAR SPACE AND SWIRL VANE EXIT GEOMETRY
    NUMBER OF VANES=        40
    THICKNESS,FT=    .01042
    ANNULAR SPACE TIP RADIUS,FT=   1.66670
    ANNULAR SPACE HUB AND VANE TIP (SPLITTER) RADIUS,FT=   1.66660
    VANE HUB RADIUS,FT=    .91660
    VANE ANGLE (+C.W.LOOKING UPSTREAM) VS.SPAN (1.0 IS SPLITTER), (DEG/DECIMAL)
    ( 64.00/1.0000)     ( 40.00/ .1111)     (   .00/ .0000)     (


DELTA P EQUALS 1.99 INCH H2O (OUTER REGISTER OPEN 40 DEG)


BURNER SWIRL SYSTEM CONDITIONS
    INLET TEMPERATURE,DEG F= 650.00000
    INLET PRESSURE,PSFA=2126.58000
    EXIT PRESSURE,PSFA=2114.70000
    VANE CASCADE DYNAMIC HEAD LOSS,"q"=   1.00000
    ANNULAR SPACE DYNAMIC HEAD LOSS,"q"=   1.00000


RADIAL DAMPER VANE EXIT CONDITIONS


R=   1.66670  PT=2126.58000  PS=2121.45800  TT=1109.70000  TS=1108.93600
V=  95.79740  VR=  95.79740  VT=    .00000  AT=    .00000  THROAT=   4.36271

FLOW,LBM/SEC=  14.99981
CIRCULATION,SQ FT/SEC=    .00000


AXIAL ANNULAR SPACE EXIT CONDITIONS


STREAMLINE R= 1.6667 PT=2121.5 PS=2114.7 TT=1109.7 TS=1108.7 RHO= .0360
  V= 110.2 VZ= 110.2 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

STREAMTUBE R= 1.6666 DM=  .0041 DGT=  .000E+00 DGX=  .142E-01 DSWIRL=   .000
                                DGP=  .000E+00 DRECIR=   13.6  (12.1)

STREAMLINE R= 1.6666 PT=2121.5 PS=2114.7 TT=1109.7 TS=1108.7 RHO= .0360
  V= 110.2 VZ= 110.2 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0000

FLOW,LBM/SEC=    .00415
SWIRL NUMBER=  .000  REFERRED TO RADIUS,FT= 1.66670
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2114.7 (2116.22)


AXIAL SWIRL VANE EXIT CONDITIONS


STREAMLINE R= 1.6666 PT=2121.5 PS=2114.7 TT=1109.7 TS=1108.7 RHO= .0360
  V= 110.2 VZ=  48.3 VT=  99.0  A= 64.00  B= 64.00  P=   .00 TAU= .0908

STREAMTUBE R= 1.6255 DM= 1.4308 DGT=  .712E+01 DGX=  .229E+01 DSWIRL=  1.866
                                DGP= -.114E+00 DRECIR=    2.6  (1.08

STREAMLINE R= 1.5833 PT=2121.5 PS=2114.4 TT=1109.7 TS=1108.6 RHO= .0360
  V= 112.4 VZ=  54.5 VT=  98.3  A= 61.00  B= 61.00  P=   .00 TAU= .0864

STREAMTUBE R= 1.5422 DM= 1.5280 DGT=  .715E+01 DGX=  .274E+01 DSWIRL=  1.566
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                                DGP= -.333E+00 DRECIR=     3.0 (1.48)

STREAMLINE R= 1.4999 PT=2121.5 PS=2114.1 TT=1109.7 TS=1108.6 RHO= .0360
  V= 114.6 VZ=  60.8 VT=  97.2  A= 58.00  B= 58.00  P=   .00 TAU= .0835

STREAMTUBE R= 1.4589 DM= 1.6074 DGT=  .703E+01 DGX=  .320E+01 DSWIRL=  1.319
                                DGP= -.535E+00 DRECIR=     3.5 (1.98)

STREAMLINE R= 1.4166 PT=2121.5 PS=2113.8 TT=1109.7 TS=1108.6 RHO= .0360
  V= 116.9 VZ=  67.1 VT=  95.8  A= 55.00  B= 55.00  P=   .00 TAU= .0816

STREAMTUBE R= 1.3756 DM= 1.6679 DGT=  .676E+01 DGX=  .364E+01 DSWIRL=  1.113
                                DGP= -.718E+00 DRECIR=     4.1 (2.58)

STREAMLINE R= 1.3333 PT=2121.5 PS=2113.5 TT=1109.7 TS=1108.5 RHO= .0360
  V= 119.2 VZ=  73.4 VT=  93.9  A= 52.00  B= 52.00  P=   .00 TAU= .0808

STREAMTUBE R= 1.2923 DM= 1.7088 DGT=  .637E+01 DGX=  .407E+01 DSWIRL=   .939
                                DGP= -.881E+00 DRECIR=     4.7 (3.18)

STREAMLINE R= 1.2499 PT=2121.5 PS=2113.2 TT=1109.7 TS=1108.5 RHO= .0360
  V= 121.5 VZ=  79.7 VT=  91.7  A= 49.00  B= 49.00  P=   .00 TAU= .0809

STREAMTUBE R= 1.2090 DM= 1.7293 DGT=  .587E+01 DGX=  .445E+01 DSWIRL=   .791
                                DGP= -.102E+01 DRECIR=     5.4 (3.88)

STREAMLINE R= 1.1666 PT=2121.5 PS=2112.9 TT=1109.7 TS=1108.4 RHO= .0360
  V= 123.8 VZ=  86.0 VT=  89.1  A= 46.00  B= 46.00  P=   .00 TAU= .0819

STREAMTUBE R= 1.1257 DM= 1.7288 DGT=  .529E+01 DGX=  .479E+01 DSWIRL=   .664
                                DGP= -.113E+01 DRECIR=     6.2 (4.68)

STREAMLINE R= 1.0833 PT=2121.5 PS=2112.6 TT=1109.7 TS=1108.4 RHO= .0360
  V= 126.1 VZ=  92.2 VT=  86.0  A= 43.00  B= 43.00  P=   .00 TAU= .0837

STREAMTUBE R= 1.0424 DM= 1.7069 DGT=  .466E+01 DGX=  .505E+01 DSWIRL=   .554
                                DGP= -.122E+01 DRECIR=     7.0 (5.48)

STREAMLINE R=  .9999 PT=2121.5 PS=2112.3 TT=1109.7 TS=1108.3 RHO= .0360
  V= 128.3 VZ=  98.3 VT=  82.5  A= 40.00  B= 40.00  P=   .00 TAU= .0866

STREAMTUBE R=  .9592 DM= 1.8901 DGT=  .217E+01 DGX=  .682E+01 DSWIRL=   .191
                                DGP= -.128E+01 DRECIR=    11.0 (9.48)

STREAMLINE R=  .9166 PT=2121.5 PS=2112.0 TT=1109.7 TS=1108.3 RHO= .0360
  V= 130.5 VZ= 130.5 VT=    .0  A=   .00  B=   .00  P=   .00 TAU= .0724

FLOW,LBM/SEC=  14.99800
SWIRL NUMBER=  .849  REFERRED TO RADIUS,FT= 1.66660
RECIRCULATION PARAMETER REFERRED TO PRESSURE,PSFA=  2114.7 (2116.22)


CONVERGED, NUMBER OF FLOW ITERATIONS=          6

SWIRLER TO TOTAL FLOW RATIO=     1.000


SYMBOL DEFINITION FOR EXIT CONDITION TABLES
    R - RADIUS,FT
    PT,PS - TOTAL,STATIC PRESSURE,PSFA
    TT,TS - TOTAL,STATIC TEMPERATURE,DEG R
    V,VZ,VT,VR - TOTAL,AXIAL,TANGENTIAL,RADIAL VELOCITY,FT/SEC
    A - PROJECTED FLOW ANGLE (ON PLANE PERP TO RADIAL LINE),DEG
    B - FLOW ANGLE (MERIDIONAL PLANE),DEG
    P - STREAMLINE SLOPE,DEG
    THROAT -AREA,SQ FT
    AT - THROAT ANGLE (OFF RADIAL LINE IN PLANE PERP TO C-L),DEG
    RHO - DENSITY,LBM/CU FT
    TAU - BLOCKAGE,FRACTION


SYMBOL DEFINITION FOR INCREMENTAL VALUES
    DM - INCREMENTAL MASS FLOW,LBM/SEC
    DGT - INCREMENTAL TANGENTIAL MOMENTUM,FT LBF
    DGX - INCREMENTAL AXIAL MOMENTUM,LBF
    DSWIRL - SWIRL NUMBER FOR INCREMENT,DIMENSIONLESS
    DGP - INCREMENTAL AXIAL PRESSURE FORCE,LBF
    DRECIR - RECIRCULATION PARAMETER FOR INCREMENT,PSFA
          - (NEGATIVE MEANS RECIRCULATION ZONE)
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